HISTORY of SANITATION

J. J. COSGROVE


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History of Sanitation

By J. J. COSGROVE

Author of

"Principles and Practice of Plumbing," "Sewage Purification and Disposal," "Wrought Pipe Drainage Systems," and "Plumbing Plans and Specifications"

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Preface

When the manuscript for this volume was prepared, there was no decided intention of publishing it in book form. Originally it was intended to appear as a serial in "Modern Sanitation," and grew out of a request from the Editor of that magazine to write an article that would trace the advancement made in sanitation from its earliest stages to the present time.

Sanitation has been given but little thought by historians, consequently, considerable study and research were necessary to dig from musty tomes and ancient records a story that would prove interesting and instructive. Having succeeded in gathering together much of interest to sanitarians, and in view of the fact that no other history of sanitation was ever written, the work was deemed worthy of a more permanent place in literature, and it was decided to put it forth in more enduring form. The book is therefore offered to the public with the fervent hope that those who read its pages will derive as much pleasure as did the author in preparing the manuscript.

J. J. Cosgrove

Philadelphia, Pennsylvania
February 15th, 1909

Publisher's Note

THE primary object of our organization is, as is universally known, to manufacture and market **"Standard"** Plumbing Fixtures, Brass Goods and other products made in our factories. In the development of an organization to accomplish this result, there has been established an Advertising and Publishing Department of no small proportions, and the "History of Sanitation" is simply the outgrowth of the work of this department. This brief statement will, we believe, serve to give the public a clear understanding of our somewhat unique position of being at the same time manufacturers and publishers.

The first serious work of the Publishing Department on a large scale was "Modern Sanitation" (established June, 1904). From this came the publication, first in serial form and later as a book, of J. J. Cosgrove's first work, "Principles and Practice of Plumbing" (book published December, 1906). The phenomenal success of the book is a matter of general knowledge, although it may not be widely known that "Principles and Practice of Plumbing" has been adopted as a text book in more than thirty universities and colleges in the United States, and bids fair to be adopted in others. This magnificent achievement has been accomplished solely on the merit of the work and without solicitation on the part of either the author or publisher.

There is now offered almost simultaneously two new books by Mr. Cosgrove, one being the volume in hand and the other "Sewage Purification and Disposal."

In "History of Sanitation," "Sewage Purification and Disposal" and "Principles and Practice of Plumbing" we feel that the literature of the craft has been enriched in an enduring manner, and that we have fully justified our appearance in the field of publishers as amply as we have our standing as manufacturers of a world-wide known and used product.

Standard Sanitary Mfg. Co.

Pittsburgh, U. S. A.

Publishing Department

Explanatory Description of Full Page Illustrations

An old fountain at Corinth, Greece, whose piping and stone construction date from about the time of the Christian era. It was standing here when St. Paul lived and taught in Corinth, and is still the only source of water supply for a large contingent of Greek housekeepers. Drinking water is carried home in jars, but washing is done on the spot, just as it was centuries ago.

This aqueduct is 937 feet long, and consists of 320 arches in two tiers, the highest arch in the lower tier being 102 feet. It is supposed to have been built in the time of Trajan.

Segovia was an ancient Roman city located in old Castile, Spain, and was the residence of the kings of Leon and Castile.

This photograph was made at the ruined palace and fortress of Tiryns, in Greece. It is regarded by archæologists as one of the oldest cities in the world, and is mentioned by name in Greek poetry of 2,000 years ago. Its rulers must have been men of great importance, as their stone palace (parts of its walls and galleries are as firm and solid as ever) was a structure of splendid dimensions and substantial character.

There is no doubt the 8 x 9-foot slab of stone seen in the picture formed the floor of a bathroom. At the farther edge there still remains the slanting groove cut in as an outlet for water.

Dipping a corpse in the holy waters of the Ganges River before burning it on the bank—a daily occurrence at Benares, India. Some worshipper may very likely drink the water only twenty feet away.

The waters of this ancient fountain were miraculously sweetened by the Prophet Elisha.

Table of Contents

CHAPTER VII

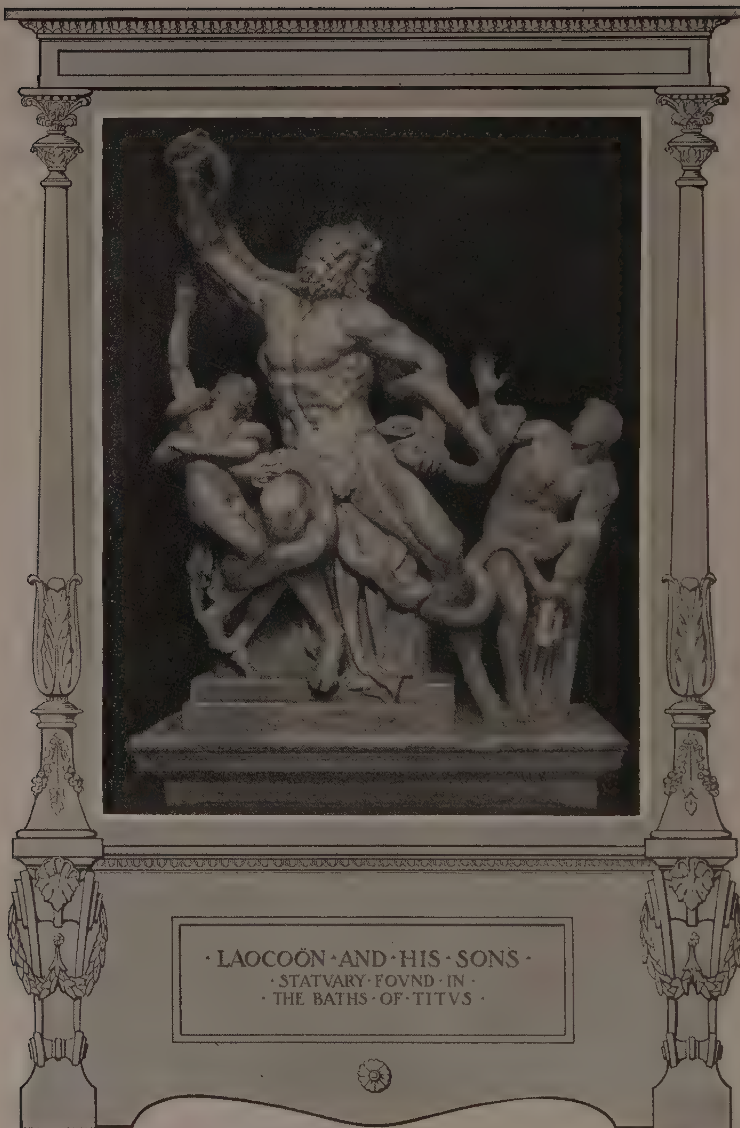
CHAPTER VIII

CHAPTER IX

CHAPTER X

List of Illustrations

Page



This group of statuary is now in the Vatican, Rome

SYNOPSIS OF CHAPTER. Sanitation of Primitive Man—Early Wells—Rebekah at the Well—Joseph's Well—The Rancho Chack.

HISTORY repeats itself. The march of progress is onward, ever onward, but it moves in cycles. A center of civilization springs up, flourishes for a time then decays; and from the ashes of the perished civilization, phœnix-like, there springs a larger, grander, more enduring civilization. Nowhere in the cycle of progress is this more noticeable than in the history of sanitation. Centers of civilization, like Jerusalem, Athens, Rome and Carthage, arose to pre-eminence in sanitary matters, built sewers, constructed aqueducts and provided for the inhabitants magnificent baths the equal of which the world has never since seen. After the splendors of Carthage and Rome, darkness succeeded; a darkness from which we slowly emerged in the sixteenth century and are now speeding on to eclipse the sanitary splendors of even the old Roman empire.

In its broadest sense, a history of sanitation is a story of the world's struggle for an adequate supply of wholesome water, and its efforts to dispose of the resultant sewage without menace to health nor offence to the sense of sight or smell. In ancient as in modern times, water

was the chief consideration of a community. Centers of population sprung up in localities where water was plentiful, and where for commercial, strategetic or other reasons, a city was built remote from a water course, great expenditures of labor and treasure were made constructing works to conduct water to the city from distant

Rebekah at the Well

springs, lakes or water courses. Ruins—still standing—of some of those engineering works give us some idea of the magnitude of the water supply for ancient cities belonging to the Roman empire.

In the early days of primitive man, sanitation was among his least concerns. He obtained water from the most convenient source, and disposed of his sewage in the least laborious way. Those who lived in the vicinity of streams solved the problem by moving to the bank, where, like their more highly civilized descendants of to-day, they drew water from the up side of the stream and returned the sewage to the water to pollute and possibly contaminate it for their neighbors lower down.

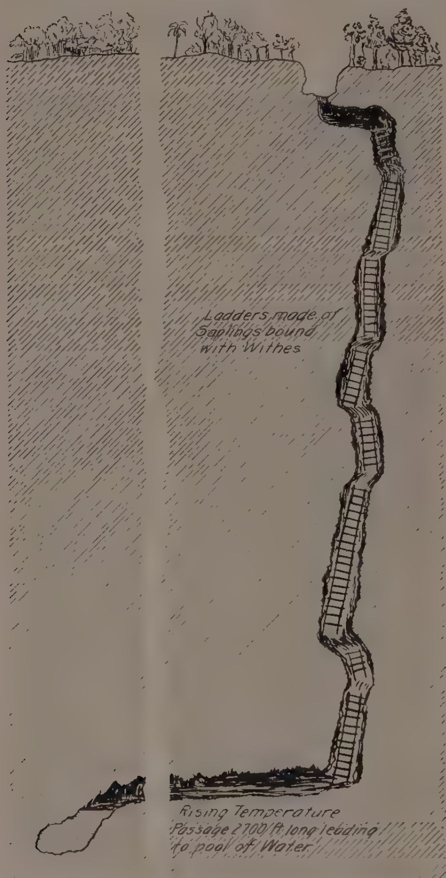
Communities living remote from natural water courses soon learned the value of wells as a source of water supply. Many mentions of wells are made in the Book of Genesis, and it is affirmed by Blackstone that at that period wells were the cause of violent and frequent contention; that the exclusive property or title to a well appeared to be vested in the first digger or occupant, even in such places where the ground and herbage remained in common.

While this statement might be true of many instances, there can be no doubt that public wells were dug even in those remote times. Indeed, the first mention made of a well, in the Book of Genesis, would indicate that its waters were free to all. Abraham's oldest servant, Eliezer, had been entrusted with the duty of selecting a wife for Abraham's son, Isaac. The servant journeyed to the ancient city of Nahor, and there "he made his camels to kneel down without the city by a well of water at the time of the evening that women go out to draw water." And he said: "Behold, I stand here by the well of water; and the daughters of the men of the city come out to draw water, and let it come to pass that the damsel to whom I shall say, Let down thy pitcher, I pray thee, that I may drink; and she shall say, Drink, and I will give thy camel drink also; Let the same be she that Thou hast appointed for thy servant, Isaac. And it came to pass that Rebekah came out, and the damsel was very fair to look upon, and she went down to the well and filled her pitcher, and the servant said, Let me I pray thee drink a little water of thy pitcher. And she said, Drink, my lord, and when she had done giving him drink, she said, I will draw water for thy camel also. And she hastened to empty her pitcher in the trough and ran again unto the well to draw water for all the camels."

In Assyria and Persia from earliest times, water has been conveyed to towns from astonishing distances in open channels, and in Egypt, also in China, gigantic works for conveying water both for domestic use and for irrigation have been in existence from remote antiquity. In China, a knowledge of the art of well drilling has existed

for centuries. Travelers speak of wells drilled by Chinese, centuries ago, to a depth of 1,500 feet.

In the valley of the Nile are many famous wells. Joseph's Well* at Cairo, near the Pyramids, is perhaps the most famous of ancient wells. It is excavated in solid rock to a depth of 297 feet and consists of two stories or lifts. The upper shaft is 18 by 24 feet and 165 feet deep; the lower shaft is 9 by 15 feet and reaches to a further depth of 132 feet. Water is raised in two lifts by means of buckets on endless chains, those for the lower level being operated by mules in a chamber at the bottom of the upper shaft, to which access is had by means of a spiral stairway winding about the well.



Well at the Rancho Chack

In America, the use of wells as a means of water supply is of great antiquity, dating back to pre-historic races. In the United States, along the valley of the Mississippi, artificially walled wells have been found that are believed to have been built by a race of people who

* *Ewbank's Hydraulics.*

preceded the Indians. Primitive tribes that lived in the hills sometimes had their ingenuity taxed to provide a water supply. In the hills or mountains of Yucatan, at Santa Ana, in the Sierra de Yucatan, there exists a well of great antiquity that shows the difficulty under which the aborigines labored in their search for water. The well is located on the Rancho Chack. It is not known whether this well was constructed by hand labor or is one of the numerous caverns in the rock, fashioned by the boundless forces of nature, and with which the hills abound. Water is reached after descending by ladder a distance of over 100 feet and traversing a passage 2,700 feet long or about half a mile in length. The rocky sides of the tunnel are worn smooth by the friction of clothes or bodies brushing against the surface, and the roof of the tunnel is black from soot and smoke from countless torches that have lighted water bearers to the spot where a pool of clear, lukewarm water bars the passage. How many centuries this little subterranean pool has supplied water to the natives of this region there is no means of ascertaining. The well is used at the present time, and perhaps when Carthage was a village, Rome a wilderness, and Christianity unthought of, this little pool of water hidden in the bowels of the earth and accessible only after traversing a dark, slippery, perilous passage, was to the Indians of that locality what the old oaken bucket was to the New England villagers of the seventeenth and eighteenth centuries.

· ANCIENT · ROMAN · FOVNTAIN · AT · CORINTH ·
· GREEK · PEASANTS · WASHING · CLOTHES ·

From Stereograph, copyright 1908 by Underwood & Underwood, N. Y.

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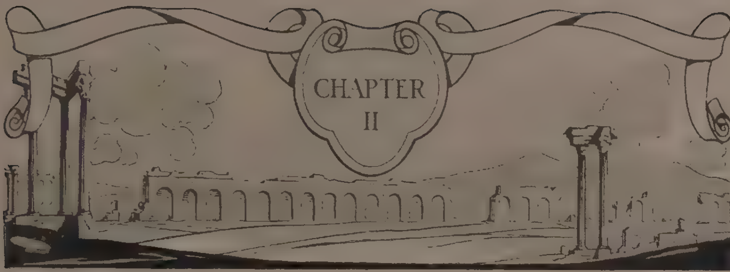


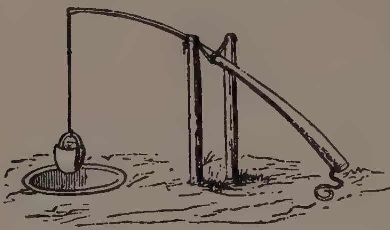
CHAPTER II

SYNOPSIS OF CHAPTER. Cisterns—Early Mention of Cisterns—Cisterns of Carthage—Early Methods of Raising Water—Water Carriers—Pool of Siloam—Pool of Solomon—Aqueducts—Carthagenian Aqueduct Aqueducts of Rome—Aqueducts of Segovia, Spain—Trophies of Marius.

THE storage of water in cisterns or reservoirs is by no means a modern practice. The earliest tribes of whom we have any traditions or records resorted to this method for providing a supply of water. In xi Kings, 18-31,

The Cisterns at Carthage. All that is left of the Ancient City

the first mention is made of cisterns in "Drink ye every one the water of his cistern." The methods employed by the ancients to construct cisterns must have been laborious and unsatisfactory. Cement at that time was unknown and bricks were not made, so that the modern cistern, as we know it, could not have existed. No doubt in some localities where clay was plentiful the cisterns were scooped out of the earth and puddled with clay, just as many reservoirs of to-day are made. This method of constructing a cistern, however, would limit the form to a cup-shaped affair, which would be very difficult to roof over. If the cisterns were not covered, as much water might be lost by evaporation as would be used by the inhabitants, so that at its best a clay-puddled cistern must have been an unsatisfactory affair. In the locality of mountains and quarries, cisterns were hewn out of the solid rock. "They have forsaken me the fountain of living waters and hewed them out cisterns, broken cisterns that can hold no water." —Jer. 2-3. Rock-hewn cisterns must have made ideal storage reservoirs for water. The darkness of the cavern



Pole and Bucket for Raising Water

Ruins of Ancient Cisterns

would prevent the growth of vegetation, while the thick walls of rock, affording a shelter from the sun, would keep the water cool and refreshing.

It is worthy of noting here that the ancients seem to have been aware of the movement of ground water through the soil, a fact that was forgotten and rediscovered in comparatively recent times. In Prov. 5-15 the statement, "Drink waters out of thine own cistern and running waters out of thine own well," would lead to this conclusion, unless, indeed, they classed a bubbling spring as a well.

Old Roman Water Wheel

The earliest known cistern or reservoir of which we have any authentic knowledge are the masonry cisterns or reservoirs that stored water for the supply of the ancient city of Carthage. These cisterns, which are wonderfully well preserved, are still to be seen on the site of the ancient Punic city, but outside of what was the walled city, before it was totally destroyed by the Romans.

Water Carrier with Jar

These cisterns were originally covered with earth, and it is due to that fact, perhaps, that they escaped destruction when the Romans razed the city. It is easy to criticise the judgment of others, and no doubt if all the facts were known, there were good and sufficient reasons why the Roman general did not destroy the cisterns and cut off the supply of water from Carthage during the siege

of that city. But in the light of our present knowledge of warfare, when a water supply is considered a vulnerable point, most carefully guarded by the besieged, and the point of most furious attack by the besiegers, when the fall of the city is considered almost accomplished when its water supply is taken, it seems an oversight on the part of the Romans not to have discovered and destroyed the cisterns, particularly as the destruction of everything in the city and environs was their mission at Carthage. It is an oversight, however, for which we may be thankful, since it preserved for future times an interesting engineering work of great magnitude for that period.

The cisterns of Carthage are eighteen in number, and each 100 feet long, 20 feet wide and nearly 20 feet deep. They lie in two long parallel rows and empty into a common gallery situated between the rows. From this center collecting gallery the water was delivered through conduits direct to the city of Carthage.

The earliest method of raising water from a well, cistern or other source of supply was by hand. This method, however, was laborious and unsatisfactory, particularly when necessary to raise large quantities of water for irrigation purposes, or to supply the inhabitants of a community at a great distance or high elevation, and it was not long before the mechanical ingenuity of our ancestors devised means for transferring this arduous duty to oxen, asses or other beasts of burden. Sometimes, as in the case of the Romans, this work is made a penal punishment, and persons found guilty of certain offenses were sentenced to the water-wheel.

About the earliest known device for raising small quantities of water was the pole and bucket, which was commonly employed in Italy, Greece and Egypt. The great antiquity of this method of raising water is proved by representations of it in Egyptian paintings. It consisted of a bucket attached to a pole that was suspended by trunnions so located that when the bucket was filled with water the thick end of the pole would just balance the combined

weight of bucket and water. This permitted its use for many hours at a time, when raising water for irrigation without greatly fatiguing the operator.

The most ingenious and highly involved form of ancient water-raising machine was a water-wheel. The method of operating a water-wheel depended much on the region where used. In Egypt, along the Nile, oxen were employed for this purpose. In China, coolies were found more satisfactory even in raising large quantities of water for irrigation purposes, which they did by walking a simple form of treadmill on the outer edges of the water-wheel. The Romans, slow at originating, but, like the Japanese, quick to recognize the value of anything new and adapt it to their purposes, borrowed the idea of the water-wheel from the Greeks or Egyptians, but made it automatic when used in streams and rivers by adding paddles that dipped into the running water and were moved by the current of the stream. Water-wheels operated by oxen were in use at Cairo up to the twelfth century, where they raised water vertically a distance of 80 feet from the Nile to an aqueduct that supplied the citadel of Cairo.

Water Carrier with Goat-skin Bag

Our present elaborate system of water distribution was of humble origin. It was not a rapid growth, but a gradual evolution. Its four principal stages were: First, distribution from natural sources by water carriers; second, aqueducts conveying water to communities where a system of sub-conduits or aqueducts conveyed the water from the main aqueduct to reservoirs at different points in a city; third, a system of distributing mains through which water was furnished to householders at certain hours only during the day; and fourth, our present system of continuous supply at all hours of the day and night. In the first stages

of water distribution, water was carried on the backs of water carriers in earthenware jars constructed especially for the purpose, or in goat or other animal skins properly tanned and sewed to hold water. While this method of water distribution is of great antiquity, it is still practiced in most tropical countries, and to this day water carriers, some with the burdens on their backs, others with goatskins of water on donkeys' backs or with jars of water in two-wheeled carts, may be seen plying their trade in Mexican and Egyptian cities.

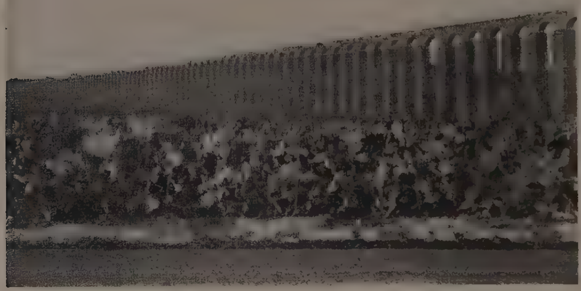
The earliest record we have of any effort to supply a community with water conveyed in tunnels or aqueducts from a great distance, dates from the year 727 B. C. King Hezekiah or Ezekias, who reigned in Jerusalem at that time, was much troubled over the poor quality of water furnished to the city and undertook to provide a better supply.

Pool of Siloam

Pool of Solomon

He had built at the gates of the city a vast reservoir, the "Pool of Siloam," but when it was completed, found that a sufficient quantity of water could not be had without conveying it from a distant source on the easterly side of a range of hills of solid rock, over which it would be impossible to convey it. In no way daunted he set to work to pierce the hills with a tunnel or aqueduct, capable of supplying the city with water. Work was commenced simultaneously at both ends of the tunnel and progressed uninterruptedly until the workmen met in the center under the mountain or hill. An inscription in old Hebrew characters, found close to Jerusalem and preserved in the Constantinople Museum, throws some interesting light on this, for that period, remarkable engineering work. Translated, the inscription reads: "The piercing is terminated. When the pick of one had not yet struck against the pick of the other, and while there was yet a distance of 3 ells, it

was possible to hear the voice of one man calling to another across the rock separating them, and the last day of the piercing, the miner's pick met against pick. The height of rock above the heads of the miners was 100 ells. Then



Aqueduct near Tunis, leading to Ancient Carthage

the water flowed into the reservoir over a length of 1,200 ells." This tunnel was cut through a mountain of solid rock. The tunnel varied in dimensions from ⅝ of a yard to a yard in width, and from 1 to 3 yards in height, according to the hardness of the rock.

The magnitude of this undertaking can be realized only when it is considered that the tunnel was constructed without the aid of blasting agents, machine drills, steam, electricity or any of the great forces or devices now controlled by man and used in modern engineering construction.

At a later period in the world's history, Roman engineers, tunneling through the rock, used fire as well as chisels to disintegrate the rock. The usual method of procedure was to build an intensely hot fire against the rock, and when the rock had been heated to the right temperature it was drenched with cold water to crack and disintegrate it. According to Pliny, vinegar was sometimes used instead of water, under the impression that it was more effective in disintegrating rock.

It is doubtful if this method was used in constructing the tunnel at Jerusalem. In fact it can be stated with considerable assurance that the entire tunnel was cut by drilling and chiseling, as the tool marks are plainly discernible. It further is evident that, as stated in the tablet found near Jerusalem, the tunnel was worked from both ends until the miners met in the center. This is evidenced by the direction of the tool marks, which plainly show that the cutting on each side of the center was done in different directions.

Prior to the construction of the tunnel, the ancient city of Jerusalem was supplied with water through two aqueducts, one of which supplied water from the famous pools of Solomon, to the south of the city, and the other poured its contents into the pools of Hezekiah, outside the walls of the city.

The Greeks were the next in point of time to construct tunnels in connection with the building of aqueducts. In 625 B. C. the Greek engineer Eupalinus constructed a tunnel 8 feet broad by 8 feet high and 4,200 feet long, through which was built a channel to supply the city of Athens with water.

This period marks the beginning in Greece and Rome of a school of architects and engineers whose works have left a lasting impression on art and engineering science, and to this

Ancient Roman Well

day are monuments of proportion and beauty of design that are studied by all students of architecture and engineering. It is quite probable that Greece supplied the first engineers that constructed aqueducts in Carthage and Rome. The similarity in design of these various works points forcibly to the conclusion that they were all designed by disciples of one school.

Whether the first aqueducts were built in Carthage or in Rome is a matter of some uncertainty, although the fact that an aqueduct supplied Carthage with water at the time it was destroyed by the Romans would point to the Carthagenian aqueduct as the prior. The first Roman aqueduct was built in the year 312 B. C., and the city of Carthage, which, after a protracted struggle of 118 years, from 265 B. C. to 147 B. C., was finally conquered and destroyed by the Romans, was at that time supplied with water from distant springs through an aqueduct.

It is quite probable that Carthage was supplied with water from two different sources. The cisterns already mentioned provided a supply of rain water for industrial and most domestic uses, while the aqueduct, the channel of which had a cross-section of 10 inches square, brought drinking water from springs in the Zaghorn Mountains, some 60 kilometers distant. The aqueduct contoured the hillside for a considerable distance, at times went under ground, and on approaching the city was carried on arches of magnitude seemingly out of proportion to the size of the channel. At present it is suffering the fate of most ancient ruins. It is used as a quarry from which stones are taken to construct buildings in nearby towns and villages.

While the ruins of aqueducts and tunnels at Jerusalem, Athens and Carthage give some idea of the skill and knowledge of hydraulic and sanitary matters possessed by the engineers of that period, we must turn to Rome and study their system of water supply, drains for sewage and the ruins of their magnificent baths to form a true conception of the skill of the early school of Roman engineers

and the lavish expenditures of treasure by the inhabitants to secure an adequate water supply for Rome. No aqueducts were built in Rome before the year 312 B. C. Prior to that time the inhabitants supplied themselves with water from the Tiber or from wells, cisterns or springs. The first aqueduct was begun by Appius Claudius, the censor, and was named after him the Aqua Appia. This aqueduct had an extreme length of 11 miles, and almost all of the work was entirely under ground. Remains of this work no longer exist. After the Aqua Appia was completed the building of aqueducts seems to have become almost a habit of the Romans, and it was not long—272 B. C.—before M. Aurius Dentatus began a second one called the Anio Vetus, which brought water from the river Anio, a distance of 43 miles. This aqueduct was constructed of stone and the water channel was lined with a thick coat of cement—no doubt Pozzolana cement—made from rock of volcanic origin, which, upon being pulverized and mixed with lime, possessed the hydraulic property of setting under water. Indeed, there can be but little doubt that were it not for this natural cement the construction of Roman aqueducts would have been more difficult to accomplish.

The water furnished by the Anio Vetus was of such poor quality that it was almost unfit for drinking. A further supply being found indispensable, the Senate commissioned

Ruins of a Roman Aqueduct

Quintus Marcius Rex, the man who had superintended the repairs of the two already built, to undertake a third, which was called after him the Aqua Marcia. This was the most pretentious aqueduct undertaken. It was 61 miles long, about 7 of which were above ground, carried on arches, and of such height that water could be delivered to the loftiest part of Capitoline Mount. A considerable number of the arches of this aqueduct are still standing. Remains are also standing of the Aqueduct Tepula (127 B. C.) and the Aqua Julia (35 B. C.), which, if we except the Herculea branch, are next in point of date. Near the city of Rome the three aqueducts were united in one line of structure, forming three separate water courses, one

Distant View of the Claudia Aqueduct

above another, the lowermost of which formed the channel of the Aqua Marcia and the uppermost that of the Aqua Julia.

Thirteen years after the Julia, the Virgo aqueduct was built. This aqueduct was 14 miles long and is said to be so named because the spring from which it is supplied was

first pointed out by a girl to some soldiers who were in search of water. This aqueduct still exists entire, having been partly restored by Nicholas V and the work completed by Pope Pius IV in 1568.

Near View of the Claudia Aqueduct

In the tenth year of the Christian era, the Augusta aqueduct was built. This aqueduct was only 6 miles long, and the water that it brought from Lake Aluetimus was of such bad quality as to be scarcely fit for drinking, on which account it is supposed that the founder, Augustus, intended it chiefly for his naumachia.

It might be interesting at this point to deviate a little from the history of the Roman aqueducts and draw aside the curtain to catch a glimpse of the aquatic sports or pastimes of a Roman emperor of that period. The naumachia of Augustus was a rectangular basin 1,800 feet long by 1,200 feet wide, in which actual sea fights between rival fleets were held for the amusement of the emperor and his friends. The combatants in these sea fights were usually captives, or criminals condemned to death, who fought as in gladiatorial combats, until one party was killed, unless saved by the clemency of the emperor. The vessels engaged in the sea fight were divided into two parties,

called respectively by names of different maritime nations, as Persians and Athenians. The sea fights were conducted on the same magnificent scale and with the same disregard of life as characterized the gladiatorial combats and other public games of the Romans held in the Colosseum. In Nero's naumachia, sea monsters were swimming around in the artificial lake to make short work of any poor unfortunate that was unlucky enough to go overboard.

In some of the sea fights exhibited by different emperors, the ships were almost equal in number to real fleets. In one battle there were 19,000 combatants and 50 ships on each side.

It was for the purpose then of supplying one of these artificial lakes with water that the Augusta aqueduct was constructed.

Perhaps the best known aqueducts of Rome are the Claudia and the Anio Novus. The completion of these waterways, which was accomplished respectively in 50 and 52 A. D., doubled the supply of water to Rome. The Claudia aqueduct was 46 miles in length and the Anio Novus 58 miles in length. The Claudia was commenced

Aqueduct in Ruins, Ephesus

by Caligula in the year 38, but was completed, as was the Anio Novus, by the Emperor Claudius.

Many other aqueducts besides those mentioned were built at different periods to add to the water supply of Rome. A table is given below showing the date of the constructions and their lengths.

The magnificence displayed by the Romans in the construction of aqueducts was not confined to the capital. Wherever Roman colonies were established, it would appear that vast sums were expended in providing the community with a suitable supply of water. Ruins of aqueducts built by the Romans may still be seen at many points in Spain, France, Africa, Greece, and even England can point to the ruins of a water tower built by this prolific school of Roman engineers. At the present time there are probably one hundred or more structures of this kind in existence, some of which are in daily use, supplying water to inhabitants of communities for whose ancestors they were built centuries ago.

ROMAN AQUEDUCTS, ARRANGED IN CHRONOLOGICAL ORDER

Name of Aqueduct	Date of Construction	Length Miles
Appia	313 B. C.	11
Anio Vetus	273 B. C.	43
Marcia	145 B. C.	61
Herculea branch		3
Tepula	127 B. C.	13
Julia	35 B. C.	15
Virgo	21 B. C.	14
Augusta	10 A. D.	6
Absietina	10 A. D.	22
Claudia	50 A. D.	46
Anio Novus	52 A. D.	58
Neronian branch	97 A. D.	2
Trajana	111 A. D.	42
Hadriana	117–1585 A. D.	15
Aurelia	162 A. D.	16
Severiana	200 A. D.	10
Antoniniana branch	212 A. D.	3
Sabina–Augusta	130–300 A. D.	15
Alexandrina	230 A. D.	15
Jova	300 A. D.	

(The miles above given are Roman miles, of 4,854 feet. The entire length of aqueduct in English miles would be 398.)

Aqueduct of Segovia, Spain

The aqueduct of Segovia, Spain, is one of the most perfect and magnificent works of the kind remaining. It is built without mortar, is entirely of stone and of great solidity. The piers are 8 feet wide by 11 feet deep, and where the aqueduct approaches the city it attains a height of about 100 feet. This aqueduct is over 2,400 feet long, is built in two tiers of arches and although almost eighteen hundred years old, still supplies water to the city. Of the 109 arches, however, 30 are of modern construction, being reproductions of the ancient arches.

The constructive details of these old water courses are as interesting as are their general design. At the mouth of each aqueduct there generally was constructed a reservoir in which to collect water from the springs or streams that supplied it, and in which impurities could settle before the clarified water was delivered into the channel. The water channel was usually formed either of stone or brick coated on the inside with cement to make it water-tight. It was arched over on top, and at certain intervals vent holes were provided through

which access could be had to the channel to make repairs. When two or more channels were carried one above another, the vent holes of the lower ones were placed in the sides. When possible, aqueducts were carried in a direct line, but frequently they were given a tortuous course either to avoid boring through hills, where their construction would have entailed too great expense, or else to avoid very deep valleys or soft marshy ground. In every aqueduct, besides the principal reservoirs at its mouth and terminal, there were intermediate ones at certain distances along its course, in which any remaining sediment might be deposited. In addition to serving as sediment basins, these reservoirs made it more easy to superintend and keep in repair the different sections, and provided service reservoirs to furnish irrigation water for fields and gardens and water for stock. The principal reservoir was that in which the aqueduct terminated. This reservoir or castella, as it was called, far exceeded any of the others in grandeur of architecture, or in magnitude and solidity of construction.

Water Tower and Roman Ruins, Chester, England

The ruins of a work of this kind that still exist on the Esquiline Hill at Rome, are about 200 feet long by 130 feet wide, and had a vaulted roof that rested on 48 immense pillars disposed to form rows so as to form 5 aisles and 75 arches. From the description of this interesting reservoir, the interior must have greatly resembled many of the covered slow-sand fillers recently constructed in this country, in which elliptical groined arches form the roof, which is carried on brick columns spaced as in the reservoirs at Rome, about 15 feet from center to center. Judging from the fact that not only the aqueducts but also the reservoirs were covered to exclude light, it seems reasonable to conclude that Roman engineers were aware that absence of light prevented or altogether checked the growth of algæ and other objectionable forms of water vegetation. Nowhere in the writings of the early historians is any mention made of trouble due to this cause, but as the water supply of Rome was obtained from both ground (spring) and surface sources, which in many cases were mixed together, the resultant mixture would have furnished the best possible soil for algæ, the ground water providing the necessary mineral food and the surface water furnishing the seed. It is quite probable, therefore, that the aqueducts and reservoirs were covered to prevent such growths.

Roman Water Pipes made of Bored-out Blocks of Stone

Besides the principal reservoir, each aqueduct had a number of smaller ones at different points in the sections they supplied, to provide that neighborhood with water. It is estimated that all told there were 247 of the auxiliary public reservoirs scattered throughout the city. These reservoirs were supplied from the principal reservoir

through pipes of lead, burned earthenware, and in some cases bored out blocks of stone. Burned earthenware pipes were generally used not only on account of their greater cheapness, but because the Romans were aware of the injurious effect of lead poisoning, and looked with suspicion on water that had been conducted through lead pipes.

When a number of individuals living in the same neighborhood had obtained a grant of water, they clubbed together and built a private reservoir into which the whole quantity allotted to them collectively was transmitted from the public reservoir. The object of private reservoirs was to facilitate the distribution of the proper amount of water to each person and to avoid puncturing the main aqueduct in too many places. When a supply of water from the aqueduct was first granted for private use, each householder granted the privilege obtained his quantity by tapping a branch supply pipe into the main aqueduct, and conducting the branch to a domestic reservoir within his own house. Later when the system of private reservoirs was adopted, each domestic supply of water was obtained from the private reservoir and piped to the domestic reservoir which was made of lead.

Trophies of Marius

The façade of an aqueduct reservoir known as the "Trophies of Marius" may be seen in the accompanying reproduction of a woodcut made in the sixteenth century. The ground plan shows part of the internal construction. The stream of water is first divided by the round projecting

buttress into two courses which are again sub-divided into five minor streams that discharge into the reservoir as indicated in the cut.

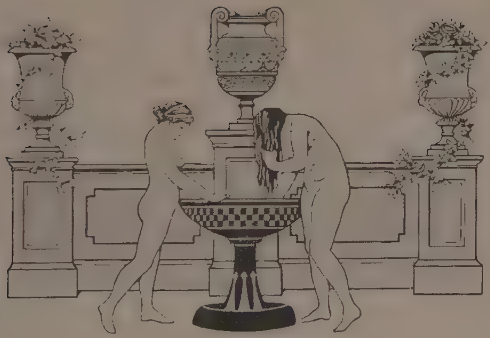
The quantity of water supplied to Rome compared favorably with the per capita allowance of water provided at the present time for the principal cities of the United States, and was far in excess of the water supplied at the present time to British and European cities. According to Clemens Herschel, however, Rome, with a population of 1,000,000 people, had a daily water supply of only 32,000,000 U. S. gallons. In estimating the quantity of water brought to the city by the system of aqueducts, Mr. Herschel makes due allowance for and deducts what he thinks might be lost by leakage, theft, water supplied to artificial lakes for sea fights, and also assumes that a certain percentage of the channels at all times were cut out of service for repairs. He makes no allowance, however, for water obtained from different sources, such as wells, springs and the Tiber River, from which, no doubt, many of the inhabitants obtained their entire supply of water. Indeed, in the year 35 B. C., M. Agrippa, as the head of the water supply system of Rome, in addition to repairing the Aqua Julia and Marcia aqueduct, supplied the city with 700 wells and 150 springs.

Old Roman Lead and Terra-cotta Pipe

There is no reason to believe that conditions in Rome were different from those existing to-day in our large cities, and it is more than probable that the poor people of Rome were but scantily supplied with water from the aqueducts. The supply obtained by them from ground sources should therefore be added to that supplied by the aqueducts, and

it would then be found, as most writers assert, that the per capita daily supply of water to Rome was equal to about 100 U. S. gallons.

Such enormous quantities of water could not be poured daily into a limited area without material and physical injury resulting if provision were not made to dispose of the surplus. Hence it was that a system of drains was evolved in Rome, which, while not the first in point of time, nevertheless were the only ones known to have been constructed by the ancients, until within a comparatively recent date ruins of sewerage systems were unearthed in Bismya, an ancient Symerian or pre-Babylonian city.



· THE · WOMEN'S · BATHS · POMPEII ·

SYNOPSIS OF CHAPTER. Early Sewage Disposal—Removal of Offensive Materials from Temples of Jerusalem—Sewage System of a Pre-Babylonian City—Sewers of Rome—The Cloaca Maxima—The Dejecti Effusive Act.

BEFORE describing the sewerage system of Rome, it might be interesting to glance backward at the efforts made prior to that time to dispose of excreta and household wastes.

It is in Deuteronomy, one of the Books of Moses, that first mention is made of the disposal of excreta: "Thou shalt have a place also without the camp, whither thou shalt go forth abroad.

"And thou shalt have a paddle upon thy weapon; and it shall be when thou wilt ease thyself abroad, thou shalt dig therewith, and shall turn back and cover that which cometh from thee."

No doubt the object of Moses in promulgating that law was to preserve cleanliness about camp and to hide offensive matter from sight in the least odorous way. Nevertheless no more sanitary method could have been adopted. Deposited as the soil was, in small quantities, just underneath the surface of the ground it was soon reduced to harmless compounds by the teeming bacteria in the living earth.

Recent explorations in Jerusalem have brought to light extensive drains for the removal from the vicinity of the temples of offensive matters peculiar to the bloody sacrifices of that ancient people; and in an August, 1905, issue of the *Scientific American*, Edgar James Banks, field

director of the Babylonian expedition of the University of Chicago, gives an interesting description of house drains and sewage disposal wells constructed at Bismya some 4,500 years ago. The following account is abstracted from that article:

"Babylonia is perfectly level. From Bagdad to the Persian Gulf there is not the slightest elevation save for the artificial mounds or an occasional changing sand drift. In most places there is a crust of hard clay upon the surface, baked by the hot sun of summer time so hard that it resembles stone. Beneath the crust, which at Bismya is seldom more than 4 feet in thickness and in places entirely lacking, is loose caving sand reaching to an unknown depth.

"Drainage in such a country, without sloping hills or streams of running water, might tax the ingenuity of the modern builder. In constructing a house, the ancient Sumerian of more than 6,000 years ago first dug a hole into the sand to a considerable depth. At Bismya several instances were found where the shaft had reached the depth of 45 feet beneath the foundation of the house. From the bottom he built up a vertical drain of large cylindrical terra cotta sections, each of which is provided with grooved flanges to receive the one above. The sections of one drain were about 19 inches in diameter and 23½ inches in height; others were larger and much shorter. The thickness of the wall was about 1.06 inches. The tiles were punctured at intervals with small holes of about ¾ inch in diameter. The section at the top of the drain was semi-spherical, fitting over it like a cap and provided with an opening to receive the water from above. Sand and potsherds were then filled in about the drain and it was ready for use. The water pouring into it was rapidly absorbed by the sand at the bottom, and if there it became clogged the water escaped through the holes in the sides of the tiles.

The temple at Bismya was provided with several such drains. One palace was discovered with four. A large

bath resembling a modern Turkish bath and provided with bitumen floor, sloping to one corner, emptied its waste water into one. The toilets in the private houses of 6,000 years ago were almost identical with those of the modern Arab house—a small oblong hole in the floor, without a seat. Several found in Bismya were provided with vertical drains beneath.

"In clearing out the drains a few of them whose openings had been exposed were filled with the drifting sand. Others were half full of the filth of long past ages. In one at the temple we removed dozens of shallow terra cotta drinking cups not unlike a large saucer in shape and size. Evidently it received the waste water of the drinking fountain and the cups had accidentally dropped within.

"In the Bismya temple platform, constructed about 2750 B. C., we discovered a horizontal drain of tile, each of which was about 3 feet long and 6 inches in diameter and not unlike in shape those at present employed. It conducted the rain water from the platform to one of the vertical drains. One tile was so well constructed that for a long time it served as a chimney for our house, until my Turkish overseer suggested that its dark, smoked end project from the battlements of the house to convince the Arabs that we were well fortified; thus it served as a gun until the close of the excavations."

The first sewers of Rome were built between 800 and 735 B. C., and therefore antedate the first aqueduct by between 440 and 487 years. It is evident, therefore, that as originally planned the sewers of Rome were intended to carry off the surface water and in other ways serve to drain the site of the ancient city. Indeed, the

The Cloaca Maxima. From an old woodcut

The Cloaca Maxima. From a Recent Photograph

Cloaca Maxima, which was constructed during the period of the Kings, from 735 to 510 B.C., was intended to drain the marshy hollow between the Capitoline, Palatine and Esquiline hills, and afterwards, by a process of development, became part of a combined sewage system for the city.

That the engineers who designed the sewerage system of Rome had a clear conception of the service expected of such drains, is evidenced by the manner in which the system was proportioned. The pipes gradually enlarged from their extremities in the buildings through all the ramifications of the system until they finally reached the outlet at a bulkhead or quay-wall in the Tiber. It is stated by early writers that so complete was this system of sewers that every street in the ancient city was drained by a branch into the Tiber.

The Cloaca Maxima was one of the largest and most celebrated of the ancient sewers. The solidity of this structure can be judged by the fact that it has been in

Egyptian Lady Having Head Sprayed, 1700 B. C.

uninterrupted service for over 2,400 years, and at the present time is still in use, with no signs of immediate failure. The arches were made of neatly jointed stones fitted together without cement. It is stated by Pliny that a cart loaded with hay could pass down the Cloaca Maxima. It should be borne in mind, however, that a Roman cart and load of hay were of smaller dimensions than a modern one. The actual dimensions of the mouth of the sewer are 11 feet wide by 12 feet high. The lateral branches of the main sewer were of a size in proportion with their requirements and in proportion to the main or trunk sewer. The dimensions of these sewers are evidenced by the service they performed for Nero, who threw into them the unfortunate victims of his nightly riots.

Greek Women Bathing

While each street in Rome was provided with an adequate sewer, it is more than probable that only a small percentage of the population had branches extending into their houses. In those that had, the latrines were located adjacent to the kitchen, where through the

Greek Bath Tubs

untrapped end of the sewer noxious gases were continually arising to vitiate the surrounding air. The only ventilation the sewers of Rome had was through these untrapped ends.

Many of the houses of Rome were lofty and inhabited near the top by the poor, who—drainage systems not extending above the first floor—had very imperfect means for carrying off rubbish and other accumulations. A practice seems to have grown up then of throwing such liquid and solid matter from the windows, sometimes to the discomfort or injury of hapless pedestrians.

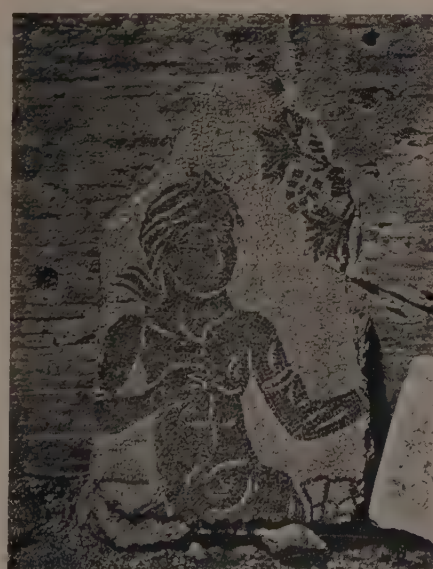
To provide against accidents due to this cause, the Dejecti Effusive Act was passed, which gave damages against a person who threw or poured out anything from a place or upper chamber upon a road frequented by passersby, or on a place where people used to stand. The act, however, gave damages only when the person was injured, but nothing was recoverable if the wearing apparel was damaged. A strange provision of this act was that it applied only in the daytime and not to the night, which, however, was the most dangerous time for passersby.


THE ROMAN AQVEDVCT OF SEGOVIA SPAIN
THE ROMAN AQVEDVCT OF SEGOVIA SPAIN

(See page iv)

SYNOPSIS OF CHAPTER. Origin of Bathing—Early Greek Baths—Roman Private Baths—Public Baths of Rome—Ruins of Baths of Caracalla—Description of the Thermæ—The Thermæ of Titus at Rome—Baths of Pompeii Heating Water for Roman Baths—Thermæ of Titus Restored.

THE value of bathing for pleasure, cleanliness and health was early realized by the ancients, who in many cases made the daily bath part of their religious ritual, with the hope of thus inducing a practice that would, from constant observance, become a habit not easy to overcome, and which would be a lasting benefit to the health of the individual and a safeguard to the community.



Mosaic from the Floor of the Baths of Caracalla

It perhaps was among the Greeks that bath tubs were first introduced. The early Greek bathing vessels (see preceding woodcuts) were made of polished marble, shaped something like a punch bowl, stood about 30 inches high, and were not occupied by the bather as in a modern bath

Ruins of the Baths of Caracalla, Rome

tub, but served only to hold the water which was applied to the bather by an attendant, who dashed or poured, as circumstances required, a vessel full of water on his head or body. Both woodcuts shown were reproduced from ancient Greek vases and convey a fair idea of the way these baths were used. One of the bathers is shown with an iron, bone, bronze or ivory instrument called a *strigilis*, in his hand, which was used to scrape off perspiration when the bather emerged from the hot room, or induced a flow by exercising in the gymnasium, which was generally connected with the baths. The inscription on the woodcut, representing men bathing, shows that this was a public bath, and is probably the earliest picture of a bathing establishment extant. The women's bath bowl differed but slightly from the men's. It was a trifle lower and considerably deeper, but the method of using was the same as for the men.

While the Greeks were prior to the Romans in the use of the bath, they considered it effeminate to use warm

water, and consequently their bathing establishments never attained the luxury and splendor that later marked the Roman baths. When bath tubs were first introduced into Rome, the wealthy inhabitants fitted up their houses with a bathroom much as do the people of our own time. As the luxury, pleasure and benefit of the bath became better known, more elaborate bathing facilities similar to a modern Turkish bath were installed. In some houses several rooms were devoted to this purpose. The anointment of the body with oils was one of the characteristics of a Roman bath. The practice was indulged in by people of both sexes, and the time when applied depended much on the treatment the bather was taking. For instance, most bathers anointed the body as the finishing touch of the bath, while some bathers applied the oil before going to the hot or sweat room.

Interior of the Frigidarium or Cold Bath, Caracalla

No luxury can be monopolized by the rich, and it was not long before public bathing establishments, in which a small entrance fee was charged, were built by private capital. Following quickly on the heels of these private enterprises, came the establishment of public baths, then,

according to the authority of Pliny, for 600 years Rome needed no medicine but the public baths.

When the public baths were first instituted they were only for the lower classes, who alone bathed in public. The people of wealth and those who held positions of state bathed in their own homes. But this monopoly of the poor was not long enjoyed. In the process of time even the emperors bathed in public among their subjects, and we read of the abandoned Gallienus amusing himself by bathing in the midst of the young and old of both sexes, men, women and children.

In the earlier stages of Roman history a much greater delicacy was observed with respect to promiscuous bathing, even among men, than obtained at a later period. Virtue passed away as wealth increased, and the public baths became places of meeting and amusement where not only did men bathe together in numbers, but even men and women stripped and bathed promiscuously in the same bath.

Some idea of the magnitude of the baths at Rome can be gained from a statement of the number of bathers they could accommodate at one time. The baths of Diocletian, which were perhaps the most commodious of them all, could accommodate at one time 3,200 bathers. One hall of this famous bathing institution was at a later date converted by Michael Angelo into the church of St. Marie de gli Angeli.

The baths of Caracalla, built A. D. 212, were perhaps the most famous of the baths of Rome. They were not as commodious however as many other baths, and they had accommodations at one time for only 1,600 bathers, or just one-half that could be accommodated by the baths of Diocletian.

The following description of the Roman baths, together with the historical sketch of the people of that period who indulged in the luxury, is abstracted from an old dictionary of Greek and Roman antiquities, published in London, England, almost a century ago. The illustrations are from woodcuts appearing in the article.

"In the earlier ages of Roman history a much greater delicacy was observed with respect to promiscuous bathing, even among the men, than was usual among the Greeks; for according to Valerius Maximus, it was deemed indecent for a father to bathe in company with his own son after he had attained the age of puberty, or son-in-law with his father-in-law, the same respectful reserve being shown to blood and affinity as was paid to the temples of the gods, toward whom it was considered an act of irreligion even to appear naked in any of the places consecrated to their worship. But virtue passed away as wealth increased, and when the thermæ came into use, not only did the men bathe together in numbers, but even men and women stripped and bathed promiscuously in the same bath. It is true, however, that the public establishment often contained separate baths for both sexes adjoining each other, as will be seen to have been also the case at the baths of Pompeii. Aulus Gellius

Outer Row of Baths, Caracalla, Rome

relates a story of a consul's wife who took a whim to bathe at Teano, a small provincial town of Campania, in the men's baths, probably because in a small town the female department, like that at Pompeii, was more confined and less convenient than that assigned to the men, and an order was consequently given to the quaestor to turn the men out. But whether the men and women were allowed to use each other's chambers indiscriminately, or that some of the public baths had only one common set of baths for both, the custom prevailed under the empire of men and women bathing indiscriminately together. This custom was forbidden by Hadrian, and Alexander Severus prohibited any baths common to both sexes from being opened in Rome.

When the public baths were first instituted they were only for the lower orders, who alone bathed in public, the people of wealth, as well as those who formed the Equestrian and Senatorian orders, using private baths in their own houses. But this monopoly was not long enjoyed, for as early even as the time of Julius Cæsar, we find no less a personage than the mother of Augustus making use of the public establishments, which were probably at that time separated from the men's, and, in process of time, even the emperors themselves bathed in public with the meanest of the people. Thus Hadrian often bathed in public among the herd, and even the virtuous Alexander Severus took his bath among the populace in the thermæ he had himself erected, as well as in those of his predecessors, and returned to the palace in his bathing dress; and the abandoned Gallienus amused himself by bathing in the midst of the young and old of both sexes, men, women and children.

The baths were opened at sunrise and closed at sunset, but in the time of Alexander Severus, it would appear that they were kept open nearly all night, for he is stated to have furnished oil for his own thermæ, which previously were not opened before daybreak and were shut before sunset; and Juvenal includes in his catalogue of female

immoralities that of taking the bath at night, which may, however, refer to private baths.

The price of a bath was a quadrant, the smallest piece of coined money from the age of Cicero downward, which was paid to the keeper of the bath. Children below a certain age were admitted free, and strangers, also foreigners, were admitted to some of the baths, if not to all, without payment.

The baths were closed when any misfortune happened to the republic, and Sentonius says that the Emperor Caligula made it a capital offence to indulge in the luxury of bathing upon any religious holiday. The baths were originally placed under the superintendence of the ædiles, whose business it was also to keep them in repair, and to see that they were kept clean and of a proper temperature.

The time usually assigned by the Romans for taking the bath was the eighth hour or shortly afterward. Before that time none but invalids were allowed to bathe in public. Vilruvins reckoned the best hours adapted for bathing to be from midday until about sunset. Pliny took his bath at the ninth hour in summer and the eighth in winter; and Martial speaks of taking a bath when fatigued and weary at the tenth hour and even later.

When the water was ready and the baths prepared, notice was given by the sound of a bell. One of these bells with the inscription Firmi Balneatoris was found in the thermæ Diocletiane, in the year 1548.

When the bath was used for health merely or cleanliness, a single one was considered sufficient at a time, and that one only when requisite. But the luxuries of the empire knew no such bounds, and the daily bath was sometimes repeated as many as seven and eight times in succession. It was the usual and constant habit of the Romans to take the bath after exercise, and previous to the principal meal; but the debauchees of the empire bathed also after eating, as well as before, in order to promote digestion so as to acquire a new appetite for fresh delicacies. Nero is said to have indulged in this practice.

Upon quitting the bath, it was usual for the Romans, as well as the Greeks, to be anointed with oil; indeed, after bathing, both sexes anointed themselves, the women as well as the men, in order that the skin might not be left harsh and rough, especially after hot water. Oil is the only ointment mentioned by Homer as used for this purpose, and Pliny says the Greeks had no better ointment at the time of the Trojan war than oil perfumed with herbs. A particular habit of body or tendency to certain complaints, sometimes required the order to be reversed and the anointment to take place before bathing. For this reason, Augustus, who suffered from nervous disorders, was accustomed to anoint himself before bathing, and a similar practice was adopted by Alexander Severus. The most usual practice, however, seems to have been to take some gentle exercise in the first instance, and then after bathing to be anointed either in the sun or in the tepid or thermal chamber, and finally to take their food.

The Romans did not content themselves with a single bath of hot or cold water, but they went through a course of baths in succession, in which the agency of air as well as water was applied. It is difficult to ascertain the precise order in which the course was usually taken, if indeed there was any general practice beyond the whim of the individual. Under medical treatment, of course, the succession would be regulated by the nature of the disease for which a cure was sought, and would vary also according to the different practice of different physicians. It is certain, however, that it was a general practice to close the pores and brace the body after the excessive perspiration of the vapor bath, either by pouring cold water over the head, or by plunging at once into the tank. Musa, the physician of Augustus, is said to have introduced the practice which became quite the fashion, in consequence of the benefit which the emperor derived from it, though Dion accuses him of having artfully caused the death of Marcellus by an improper application of the same treatment. In other cases it was considered conducive to health to pour warm

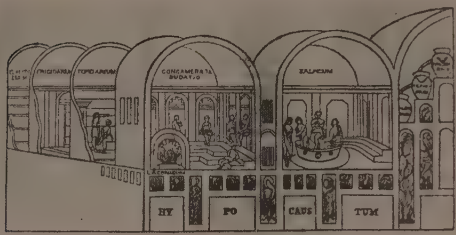
water over the head before the vapor bath, and cold water immediately after it; and at other times a succession of warm, tepid and cold water was resorted to.

The two physicians, Galen and Celsus, differ in some respects as to the order in which the baths should be taken; the former recommending first the hot air of laconicum, next the bath of warm water, afterward the cold, and finally to be well rubbed; while the latter recommends his patients first to sweat for a short time in the tepid chamber without undressing, then to proceed into the thermal chamber, and after having gone through a regular course of perspiration there, not to descend into the warm bath, but to pour a quantity of warm water over the head, then tepid, and finally cold; afterward to be scraped with the strigil and finally rubbed dry and anointed. Such in all probability was the usual habit of the Romans when the bath was resorted to as a daily source of pleasure, and not for any particular medical treatment; the more so as it resembles in many respects the system of bathing still in practice among the Orientals who succeeded by conquest to the luxuries of the enervated Greeks and Romans.

Having thus detailed from classical authorities the general habits of the Romans in connection with their systems of bathing, it now remains to examine and explain the internal arrangements of the structures which contained their baths, which will serve as a practical commentary upon all that has been said. Indeed, there are more ample and better materials for acquiring a thorough insight into Roman manners in this one particular than for any of the other usages connected with their daily habit.

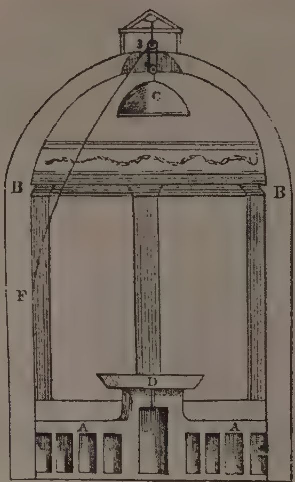
In order to make the subjoined description clear, a reproduction from an old woodcut of a fresco painting on the walls of the thermæ of Titus at Rome, is here reproduced, showing in broken perspective the general arrangement of one of the baths known as the thermæ. Heat was supplied to warm the apartments and the water used in the baths by the furnace shown extending under the entire floor of the establishment. This furnace was known as a

Hypocustum. To the right may be seen the vessels in which water for the baths was heated. The topmost vessel, the Frigidarium, contained cold water from which the hot water tanks and the various baths were supplied. Next in order is the tepidarium, in which water of moderate temperature was stored, and in the lowest, the caldarium, was heated the hottest water used in the baths.



Thermæ of Titus at Rome

After the end of the republic, large establishments used to have a separate steam bath, the laconicum, and in this apartment, or sometimes adjoining the tepidarium, was the Clipeus, a small circular chamber covered by a cupola. The Clipeus received its light through an aperture in the center of the dome, and this aperture served also as a vent from the chamber. The Clipeus was heated by means of a separate heating apparatus, and its temperature could be raised to an enormous degree or could be regulated to suit the bather by raising or lowering the shield.



Clipeus. From an old woodcut

The tepidarium, as the name

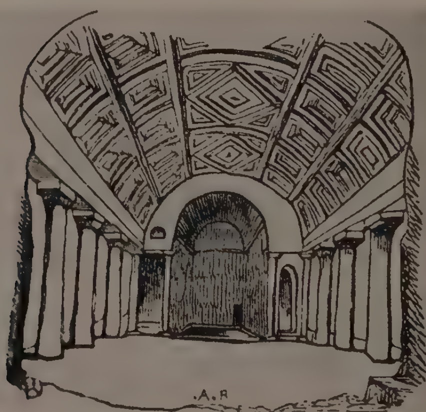
would imply, was a room in which a moderately warm bath could be taken and where the process of dry rubbing also took place. In the balneum a hot bath could be taken, originally in a tub, but in later times in a large reservoir; and in the frigidarium a cold plunge could be had. The elæothesium was the anointing room where the body was rubbed with oil and massaged.

A good idea of the general layout of a Roman bath can be gained from the accompanying woodcut, showing the ground floor plan of the baths of Pompeii. The baths, as may be seen by the illustration, are nearly surrounded on three sides by houses and shops. The whole building, which comprises a double set of baths, has six different entrances from the street, one of which, A, gives admission to the smaller set only, which was appropriated to the women, and five others to the male department, of which two, B and C, communicate directly with the furnaces, and the other three, D, E, F, with the bathing apartments, of which F, the nearest to the Forum, was the principal one; the other two, D and E, being on opposite sides of the building served for the convenience of those who lived on the north and east sides of the city. To have a variety of entrances was one of the qualities considered necessary to a well constructed set of baths.

Floor Plan of the Baths of Pompeii
From an old woodcut

Passing through the principal entrance, F, which is removed from the street by a narrow footway, and after descending three steps, the bather finds upon his left hand

a small chamber or toilet room, 1, which contains a latrine. From passage, F, he proceeded to covered portico, 2, which ran around three sides of an open court, 3, and this portico and court together formed the vestibule of the baths, in which servants belonging to the establishment, as well as such of the slaves and attendants of the great and wealthy, whose services were not required in the interior, waited. Within the court the keeper of the baths who exacted the fee paid by each visitor, was also stationed, and accordingly in it was found the box for holding the money. The room, 4, which runs back from the portico, might have been apportioned to him, or if not, it might have been a waiting room for the convenience of the better classes while waiting the return of their acquaintances from the interior. In this court, likewise, as being the most public place, advertisements for the theater and other announcements of general interest were posted, one of which, announcing a gladiatorial show, still remains. The passageway, 5, is the corridor which leads from the entrance, E, to the vestibule; and the cell, 6, is a toilet room similar to 1. Number 7 is a passage of communication which leads into the chamber, 8, which served as a room for undressing. This room is also accessible from the street by the door, D, through the corridor, 9, in which a small niche is observable, which probably served for the station of another doorkeeper, who collected money from those entering from the north street. Here, then, is the center



Frigidarium. From an old woodcut

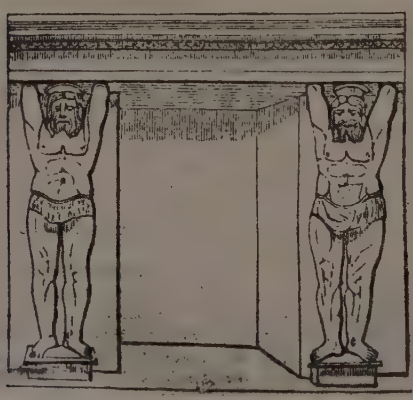
in which all the persons must have met before entering into the interior of the baths; and its locality, as well as other characteristic features of its fitting up, leave no room to doubt that it served as an undressing room. It does not appear that any general rule of construction was followed by the architects of antiquity with regard to the locality and temperature best adapted for a dressing room. The bathers were expected to take off their garments in the dressing room, not being permitted to enter the interior unless naked. The clothes were then delivered to a class of slaves whose duty it was to take charge of them. These men were notorious for dishonesty, and leagued with all the thieves of the city, so that they connived at the robberies they were placed there to prevent. To so great an extent were these robberies carried, that very severe laws were finally enacted making the crime of stealing from a bath a capital offence.

To return to the chamber itself, it is vaulted and spacious, with stone seats along two sides of the wall and a step for the feet below, slightly raised from the floor. Holes can still be seen in the walls which might have served for pegs on which the garments were hung when taken off; for in a small provincial town like Pompeii, where a robbery committed in the bath could scarcely escape detection, there would be no necessity for slaves to take charge of them. The dressing room was lighted by a window closed with glass, and the walls and ceilings were ornamented with stucco mouldings and painted yellow. There are no less than six doors to this chamber: one leading to the entrance, E, another to the entrance, D, a third to the small room, 11, a fourth to the furnaces, a fifth to the tepid apartment, and the sixth opened upon the cold baths, 10. The bath, which is coated with white marble, is 12 feet 10 inches in diameter, about 3 feet deep and has two marble steps to facilitate the descent into it, and a seat surrounding it at a depth of 10 inches from the bottom, for the purpose of enabling the bathers to sit down and wash themselves. It is probable that many

persons contented themselves with cold baths only, instead of going through the severe course of perspiration in the warm apartments; and as the frigidarium could have had no effect alone in baths like these, the natatio must be referred to when it is said that at one period cold baths were in such request that scarcely any others were used.

There is a platform or ambulatory around the bath, also of marble, and four inches of the same material disposed at regular intervals around the walls, with pedestals for statues probably placed in them. The ceiling is vaulted and the chamber lighted by a window in the center. The annexed woodcut represents a frigidarium with its cold bath at one extremity, supposed to have formed a part of the Formain Villa of Cicero, to whose age the style of construction, the use of the simple Doric order, undoubtedly belongs. The bath itself, into which water still continues to flow from a neighboring spring, is placed under the alcove, and the two doors on each side opened into small chambers.

In the cold bath of Pompeii the water ran into the basin through a spout of bronze and was carried off again through a conduit on the opposite side. It was also furnished with a waste pipe under the coping to prevent the water from running over.



Atlantes. From an old woodcut

No. 11 is a small chamber on the side opposite to the frigidarium, which might have served for shaving or for keeping unguents or strigils; and from the centers of the side of the frigidarium, the bather who

intended to go through the process of warm bathing and sudation entered into 12, the tepidarium.

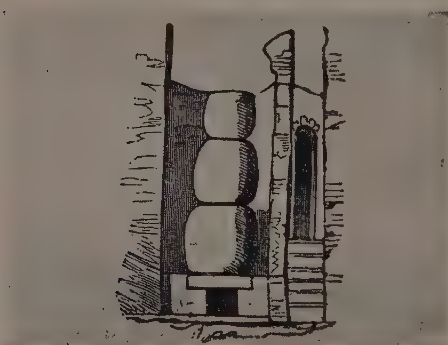
The tepidarium did not contain water, either at Pompeii or at the baths of Hippias, but was merely heated with warm air of an agreeable temperature, in order to prepare the body for the great heat of the vapor and warm baths; and, upon returning, to obviate the danger of too sudden transition to the open air.

In the baths of Pompeii, this chamber served likewise as a disrobing room for those who took the warm bath, for which purpose the fittings up are evidently adapted, the walls being divided into a number of separate compartments or recesses for receiving the garments when taken off. One of these compartments, known as an Atlantes, is shown in the annexed woodcut.

In addition to this service there can be little doubt that this apartment was used as a depository for unguents and a room for anointing, which service was performed by slaves. For the purpose of anointing, the common people used oil simply or sometimes scented, but the more wealthy classes indulged in the greatest extravagances with regard to their perfumes and unguents. These they evidently procured from the elæothesium of the baths, or brought with them in small glass bottles, hundreds of which have been discovered in different excavations made in various parts of Italy.

From the tepidarium, a door which closed by its own weight, to prevent the admission of cold air, opened into No. 13, the thermal chamber. After having gone through the regular course of perspiration, the Romans made use of instruments called strigils, to scrape off the perspiration, much in the same way as we are accustomed to scrape the sweat off a horse with a piece of iron hoop after he has run a heat or come in from violent exercise. These instruments, many of which have been discovered among the ruins of the various baths of antiquity, were made of bone, bronze, iron and silver. The poorer classes were obliged to scrape themselves, but the more wealthy took their

slaves to the baths for the purpose, a fact which is elucidated by a curious story related by Spartianus. The Emperor while bathing one day, observing an old soldier, whom he had formerly known among the legions, rubbing his back as the cattle do against the marble walls of the chamber, asked him why he converted the walls into a strigil, and learning that he was too poor to keep a slave he gave him one, and money for his maintenance. On the following day, upon his return to the bath, he found a whole row of old men rubbing themselves in the same manner against the wall, in the hope of experiencing the same good fortune from the prince's liberality; but instead of taking the hint, he had them all called up and told them to scrub one another.



Coppers for Heating Water. From an old woodcut

The strigil was by no means a blunt instrument, consequently its edge was softened by the application of oil which was dropped on it from a small vessel. This vessel had a narrow neck, so as to discharge its contents drop by drop. Augustus is related to have suffered from an over violent use of this instrument. Invalids and persons of delicate habit made use of sponges, which Pliny says answered for towels as well as strigils. They were finally dried with towels and anointed.

The common people were supplied with these necessaries in the baths, but the more wealthy carried their own with them.

After the operation of scraping and rubbing dry, they retired into or remained in the tepidarium until they thought it prudent to encounter the open air. But it does not appear to have been customary to bathe in the water,

when there was any, which was not the case at Pompeii nor at the Baths of Hippias, either of the tepidarium or frigidarium; the temperature only of the atmosphere in the two chambers being of consequence to break the sudden change from the extreme hot to cold. Returning now to the frigidarium, 8, which according to the directions of Vitruvius has a passage, 14, communicating with the mouth of the furnace, *e*, and passing down that passage we reach the chamber, 15, into which the præfurnium projects, and which has also an entrance from the street, B, appropriated to those who had charge of the fires. There are two stairways in it, one leading to the roof of the baths, and the other to the coppers which contained the water. Of these there were three, one of which contained the hot water, caldarium; the second, the tepid, tepidarium; and the last, the cold, frigidarium. The warm water was introduced into the warm bath by means of a conduit pipe, marked on the plan, and conducted through the wall. Underneath the caldarium was placed the furnace which served to heat the water and give out streams of warm air into the hollow cells of the hypocanstum. These coppers were constructed in the same manner as is represented in the engraving from the Thermæ of Titus; the one containing hot water being placed immediately over the furnace, and as the water was drawn out from these it was supplied from the next, the tepidarium, which was already considerably heated, from its contiguity to the furnace and the hypocaust below it, so that it supplied the deficiency of the former without materially diminishing its temperature; and the space in the last two was in turn filled up from the farthest removed, which contained the cold water received direct from the square reservoir behind them. Behind the coppers there is another corridor, 16, leading into the court, 17, appropriated to the servants of the baths, and which has also the conveniences of an immediate communication with the street by the door, C.

We now proceed to the adjoining set of baths, which were assigned to the women. The entrance is by the

door, A, which conducts into a small vestibule, 18, thence into the apodyterium, 19, which, like the one in the men's baths, has a seat on either side built up against the wall. This room opens upon a cold bath, 20, answering to the natiatio of the other set, but of much smaller dimensions. There are four steps on the inside to descend into it. Opposite to the door of entrance there is another doorway which leads to the tepidarium, 21, which also communicates with the thermal chamber, 22, on one side of which is a warm bath in a square recess. The floor of this chamber is suspended and its walls perforated for flues, like the corresponding one in the men's baths.

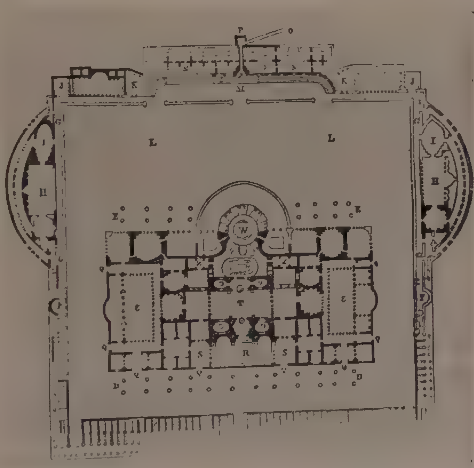
The comparative smallness and inferiority of the fittings up in this suit of baths has induced some Italian antiquaries to throw a doubt upon the fact of their being assigned to women, and ingeniously suggest that they were a set of old baths, to which the larger ones were subsequently added when they became too small for the increasing wealth and population of the city. But the story already quoted of the consul's wife who turned the men out of their bath at Teanum for her convenience, seems sufficiently to negative such a supposition and to prove that the inhabitants of ancient Italy, if not more selfish, were certainly less gallant than their successors. In addition to this, Vitruvius expressly enjoins that the baths of the men and women, though separate, should be contiguous to each other, in order that they might be supplied from the same boilers and hypocaust; directions that are here fulfilled to the letter, as a glance at the plans will demonstrate.

Notwithstanding the ample account which has been given of the plans and usages respecting baths in general, something yet remains to be said about that particular class denominated *thermæ*, of which establishment the baths, in fact, constituted the smallest part. The thermæ, properly speaking, were a Roman adaptation of the Greek gymnasium. The thermæ contained a system of baths in conjunction with conveniences for athletic games and youthful sports, places in which rhetoricians declaimed, poets recited

and philosophers lectured, as well as porticos and vestibules for the idle, and libraries for the studious. They were decorated with the finest objects of art, both in painting and sculpture, covered with precious marbles and adorned with fountains and shaded walks. It may be said that they began and ended with the Empire, for it was not until the time of Augustus that these magnificent structures were commenced. M. Agrippa was the first who afforded these luxuries to his countrymen by bequeathing to them the thermæ and gardens which he had erected in the Campus Martius. The Pantheon, now existing at Rome, served originally as a vestibule to these baths; and, as it was considered too magnificent for the purpose, it is supposed that Agrippa added the portico and consecrated it as a temple, for which use it still serves.

The example set by Agrippa was followed by Nero and afterward by Titus, the ruins of whose thermæ are still visible, covering a vast extent, partly under ground and partly above the Esquiline Hill.

Previous to the erection of these establishments for the use of the population, it was customary, for those who sought the favor of the people, to give them a day's bathing free of expense.



Ground Plan of Thermæ of Caracalla. From an old woodcut

Thus, according to Divi Cassius, Faustus, the son of Sulla, furnished warm baths and oil gratis to the people for one day; and Augustus, on one occasion, furnished warm baths and barbers to the people for

the same period free of expense, and at another time for a whole year to the women as well as the men. From thence it is fair to infer that the quadrant paid for admission to the balnea was not exacted at the thermæ, which as being the works of the emperors, would naturally be opened with imperial generosity to all, and without any charge, otherwise the whole city would have thronged to the establishment bequeathed to them by Agrippa; and in confirmation of this opinion it might be remarked that the old establishments, which were probably erected by private enterprises, were termed Meritorial.

Most, if not all, of the other regulations previously detailed as relating to the economy of the baths, apply equally to the thermæ; but it is in these establishments especially that the dissolute conduct of the emperors and other luxurious indulgence of the people in general, as detailed in the compositions of the satirists and later writers, must be considered to refer.

Although considerable remains of the Roman thermæ are still visible, yet, from the very ruinous state in which they are found, we are far from being able to arrive at the same accurate knowledge of their component parts and the usages to which they were applied, as has been done with respect to the balnea; or, indeed, to discover a satisfactory mode of reconciling their constructive details with the description left us by Vitruvious and Lucian. All, indeed, is doubt and guesswork. Each of the learned men who have pretended to give an account of their contents differing in all the essential particulars from one another; and yet the general similarity of the ground plan of the three which still remain cannot fail to strike even a superficial observer; so great indeed that it is impossible not to perceive at once that they were all constructed upon a similar plan. Not, however, to discuss the subject without enabling the reader to form something like a general idea of these enormous edifices, which from their extent and magnificence have been likened to provinces, a ground plan of the thermæ of Caracalla is annexed, which are the best

preserved among those remaining, and which were perhaps more splendid than all the rest. Those apartments of which the use is ascertained with the appearances of probability, will be alone marked and explained. The dark parts represent the remains still visible; the open lines are restorations.

A is a portico fronting the street made by Caracalla when he constructed his thermæ. B are separate bathing-rooms, either for the use of the common people, or perhaps for any person who did not wish to bathe in public. C are apodyteria attached to them. D, D and E, E, the porticos. F, F, exedra in which there were seats for the philosophers to hold their conversations. G, passages open to the air. H, H, sladra. I, I, possibly schools or academies where public lectures were delivered. J, J and K, K, rooms appropriated to the servants of the bath. In the latter are staircases for ascending to the principal reservoir. L, space occupied by walks and shrubberies. M, the arena or stadium in which the youth performed their exercises, with seats for spectators. N, N, reservoirs with upper stories; O, aqueduct which supplied the baths. P, cistern.

Hypocaust for Heating Water, Thermæ of Caracalla
From an old woodcut

This external range of buildings occupies one mile in circuit.

We now come to the arrangement of the interior, for which it is very difficult to assign satisfactory destinations.

Q represents the principal entrances, of which there were eight. R is the natiatio or cold water baths to which the direct entrance from the portico is by a vestibule on either side marked S, and which is surrounded by a set of chambers that serve most probably as rooms for undressing and anointing.

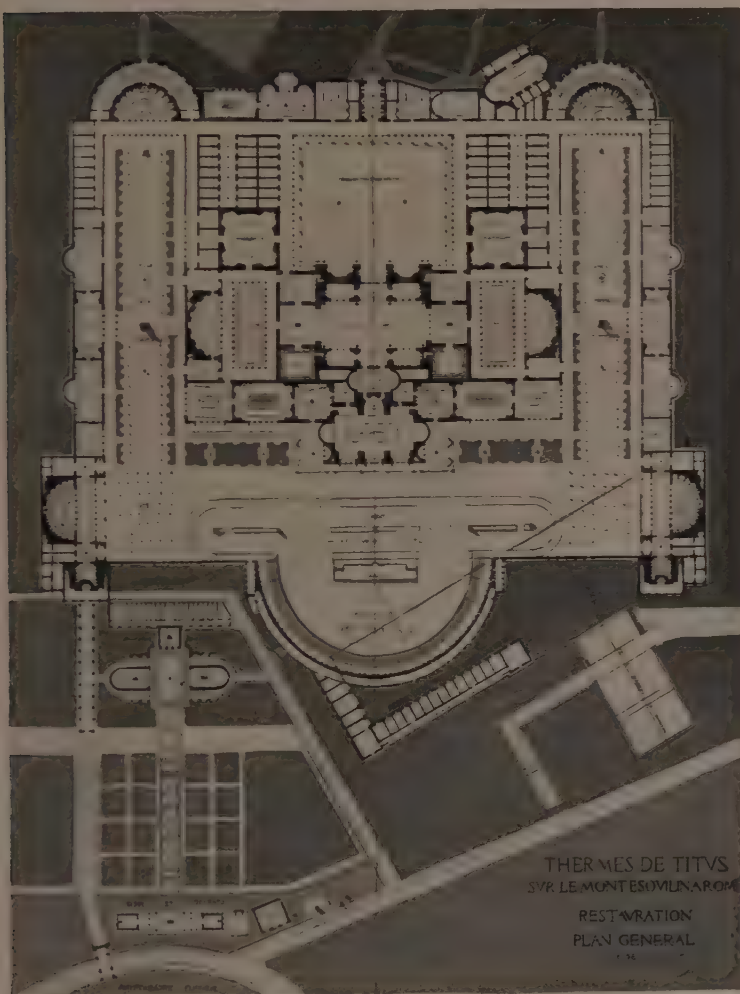
Those nearest to the peristyle were, perhaps, where the powder was kept which the wrestlers used in order to obtain a firmer grip upon their adversaries.

The inferior quality of the ornaments which these apartments had, and the staircases in two of them, afford evidences that they were occupied by menials. T is considered to be the tepidarium with four warm baths taken out of its four angles, and two labra on its two flanks. There are steps for descending into the baths, in one of which traces of the conduit are still manifest. It would appear that the center part of this apartment served as a tepidarium, having a cold water lavatory in four of its corners. The center part, like that also of the preceding apartment, is supported by eight immense columns.

The apartments beyond this, which are too much dilapidated to be restored with any degree of certainty, contained, of course, the laconium and sudatories, for which the round chamber, W, and its appurtenances seem to be

Restoration of Thermæ of Titus. (Restored by Leclerc)

adapted, and which are also contiguous to the reservoirs, Z, Z'. The apartments e, e' are probably places where youths

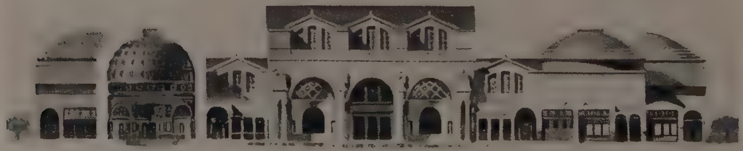


Plan of the Thermæ of Titus, Rome. (Restored by Leclerc)

were taught their exercises, with the appurtenances belonging to them. The chambers on the other side, which

are not marked, probably served for the exercises in bad weather. These baths contained an upper story, of which nothing remains beyond what is just sufficient to indicate the fact. It will be observed that there is no part of the bathing department separate from the rest which could be assigned to the use of women exclusively. From this it must be inferred either that both sexes always bathed together promiscuously in the thermæ, or that the women were excluded altogether from these establishments.

It remains to explain the manner in which the immense body of water required for the supply of a set of baths in the thermæ was heated. This has been done very satisfactorily by Piranesi and Cameron, as may be seen by a reference to the two sectional elevations showing the reservoir and aqueducts belonging to the Thermæ of Caracalla. A are arches of the aqueduct which conveyed the water into the reservoir, B, whence it flowed into the upper range of cells through the aperture at C, and thence again descended into the lower ones by the aperture, D, which were placed immediately over the hypocaust, E, the furnace of which can be seen in the transverse section at F. There were thirty-two of these cells arranged in two rows over the hypocaust, sixteen on each side, and all communicating with one another, and over these a similar number similarly arranged, which communicated with those below by the aperture at D. The parting walls between these cells were likewise perforated with flues which served to disseminate the heat all around the whole body of water. When the water was sufficiently warm it was



Sectional Elevation, Thermæ of Titus, Rome. (Restored by Leclerc.)

turned on to the baths through pipes conducted likewise through flues in order to prevent the loss of temperature during passage, and the lower reservoir was supplied as fast as water was drawn off from the reservoir next above,

Frigidarium, Thermæ of Caracalla, Rome. (Restored by Viollet-le-Duc)

which in turn was supplied with water from the topmost tier and the aqueduct.

Perhaps a better idea of the thermæ can be had by an examination of the plan of the Thermæ of Titus, Rome, restored by Leclerc, also the sectional elevation and front elevation of the same bath, restored by the same artist. The original drawings, which won the *Grand Prix de Rome*, are preserved in the library of the Ecole des Beaux-Arts, Paris. A restoration by Viollet-le-Duc, which appeared with the other restorations in the June, 1906, number of the *Architectural Record*, conveys a very good idea of the interior of a frigidarium.

·INTERIOR·VIEW·OF·AQVEDVCT·
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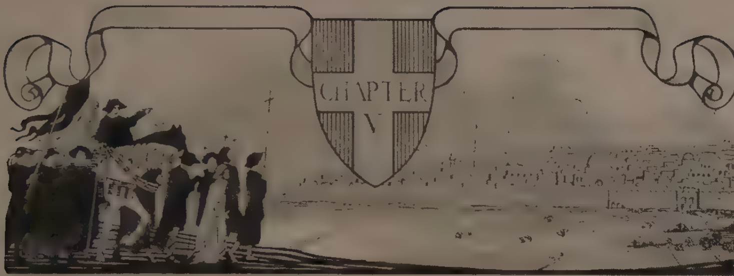


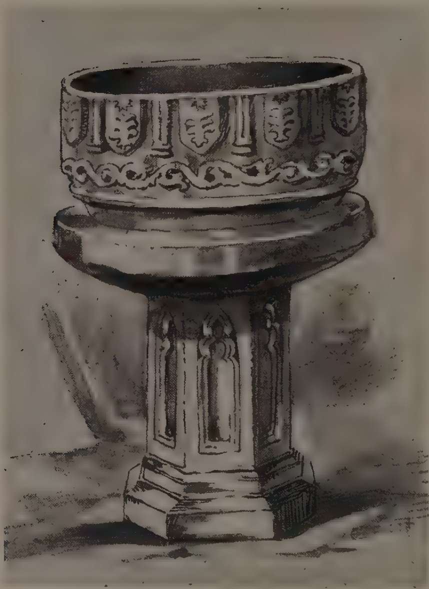
SYNOPSIS OF CHAPTER. Fall of the Roman Empire—Succeeding Period known as the Dark Ages—Sanitation during the Dark Ages—Beginning of Material Progress in Sanitation—Pilgrimages to Juggernaut—Water Supply to Paris—London Water Supply—Aqueduct of Zempoala, Mexico.

DURING the period following the fall of Rome, the empire was overrun by barbarians from the north, and the magnificent baths, aqueducts and public edifices reared by the Romans with such painstaking care were suffered to fall into decay. So little in sympathy were the barbarians with the people they conquered and their institutions, that in time the inhabitants of many localities even forgot the uses to which the old works had been put; and had it not been for the Popes the supply of water to the city of Rome would have been cut off completely, while as it was the service was frequently interrupted.

Following the fall of the Roman Empire there was a period of over one thousand years of intellectual darkness, during which no material progress was made; indeed, instead of progress a retrograde movement set in which left a lasting impression on the times. The little spark of knowledge that survived this period burned in the monasteries of the monks, who treasured and kept alive the spark of civilization.

The Dark Ages, as this period is called, if lacking in progress, were replete with adventure. During this period, which might equally well be called the Age of Romance, there sprung up a brotherhood of men noted for skill in combat, who were dubbed knights. There also spread a

creed about that time that uncleanliness was next to godliness, and clergy and laymen vied with each other to see which could live in the most filthy manner. They associated in there minds luxury and cleanliness as inconsistent with godliness, while squalor and bodily filth were considered as outward indications of inward piety and sanctification. So it came to pass that bathing, instead of a daily practice, became uncommon; homes and inhabitants became filthy and streams polluted. Such violations of sanitary principles could not continue indefinitely without evil results, and scourge after scourge of filth diseases that swept over Europe and Asia, claiming over 40,000,000 victims, were due to the unsanitary condition that prevailed.



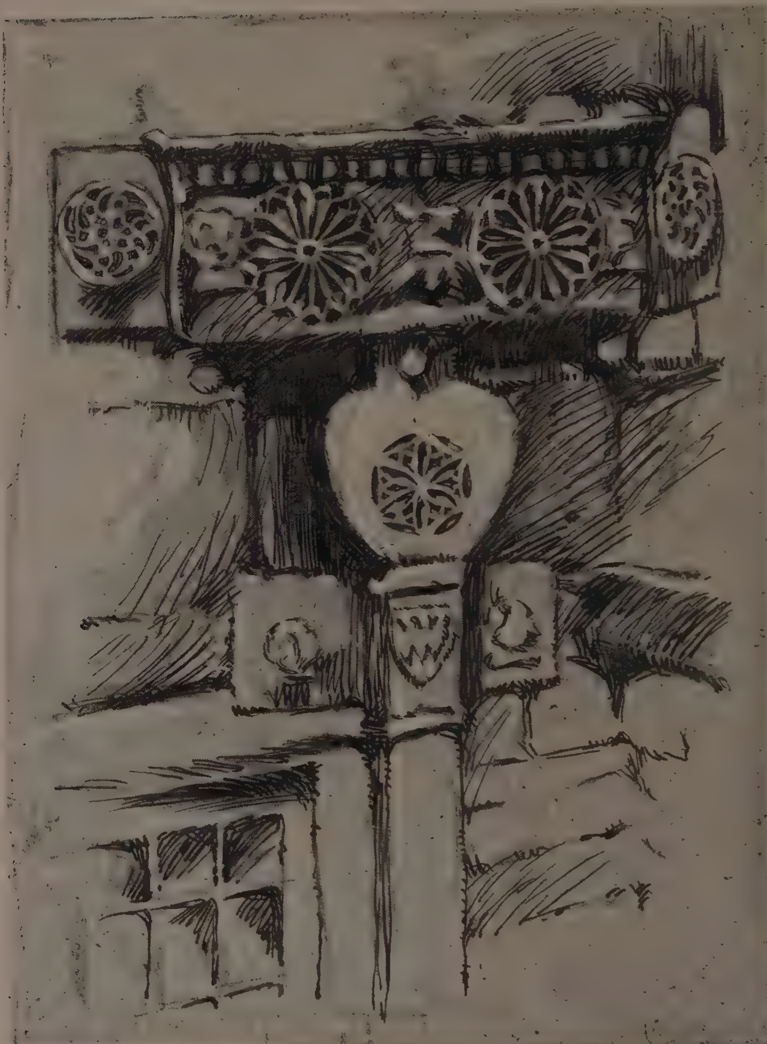
Destroyed Lead Font, Great Plumstead, Norfolk

The restless, seething, venturesome spirit of the times and the emotional zeal displayed in religious matters contributed greatly to the spread of pestilence. The crusades, starting out with a romantic and religious fervor, but with no set rules of conduct for guidance, and lacking a leader strong enough in discipline to hold in check men whose only claim to distinction lay in their powers in a tilt and their love of battle, soon degenerated into the most disorderly and lewd of rabble. Women camp-followers joined their fortunes with that of the knights, who in most cases forgot the object of the crusade, and gave themselves up to indolence and debauchery. Sanitary precautions were

dispensed with on the march, and the result was that wherever the crusaders went they left sickness and pestilence in their wake.

Pilgrimages to the holy shrines, which drew together thousands of human beings without adequate shelter or food, also served to spread contagious diseases throughout the land. Perhaps the best picture of a pilgrimage which, while of a latter date, will still serve to show the unsanitary conditions when thousands of people are brought together without food or shelter, can be had from a report of Dr. Simmons, of the Yokahama Board of Health. In speaking of a latter-day pilgrimage in India, he says: "The drinking-water supply is derived from wells, so-called 'tanks' or artificial ponds and the water courses of the country. The wells generally resemble those of other parts of Asia. The tanks are excavations made for the purpose of collecting the surface water during the rainy season and storing it up for the dry. Necessarily they are mere stagnant pools. The water is used not only to quench thirst, but is said to be drunk as a sacred duty. At the same time, the reservoir serves as a large washing tub for clothes, no matter how dirty or in what soiled condition, and for personal bathing. Many of the watercourses are sacred; notably the Ganges, a river 1,600 miles long, in whose waters it is the religious duty of millions, not only those living near its banks, but for pilgrims, to bathe and to cast their dead. The Hindoo cannot be made to use a

Leaden Cup, of the time of Vespasian, found in Rome. The band was decorated with colored glass



Lead Pipehead and Pipe

latrine. In the cities he digs a hole in his habitation; in the country he seeks the fields, the hillside, the banks of streams and rivers when obliged to obey the calls of

nature. Hence it is that the vicinity of towns and the banks of the tanks and water courses are reeking with filth of the worst description, which is of necessity washed into the public water supply with every rainfall. Add to this the misery of pilgrims, then poverty and disease and the terrible crowding into the numerous towns which contain

Lead Cistern with the Arms of the Fishmongers' Company, in the possession of Mr. Merthyr Guest

some temple or shrine, the object of their devotion, and we can see how India has become and remains the hotbed of the cholera epidemic." In the United States official report the horrors incident upon the pilgrimages are detailed with appalling minuteness. W. W. Hunter, in his "Orissa," states that twenty-four high festivals take place annually at Juggernaut. At one of them, about Easter, 40,000 persons indulge in hemp and hasheesh to a shocking degree. For weeks before the car festival, in June and July, pilgrims come trooping in by thousands every day. They are fed by the temple cooks to the number of 90,000.

Over 100,000 men and women, many of them unaccustomed to work or exposure, tug and strain at the car until they drop exhausted and block the road with their bodies. During every month of the year a stream of devotees flows along the great Orissa road from Calcutta, and every village for three hundred miles has its pilgrim encampments.

Car of Juggernaut

The people travel in small bands, which at the time of the great feasts actually touch each other. Five-sixths of the whole are females and ninety-five per cent. travel on foot, many of them marching hundreds and even thousands of miles, a contingent having been drummed up from every town or village in India by one or other of the three thousand emissaries of the temple, who scour the country in all

directions in search of dupes. When those pilgrims who have not died on the road arrive at their journey's end, emaciated, with feet bound up in rags and plastered with mud and dirt, they rush into the sacred tanks or the sea and emerge to dress in clean garments. Disease and death make havoc with them during their stay; corpses are buried in holes scooped in the sand, and the hillocks are covered with bones and skulls washed from their shallow graves by the tropical rains. The temple kitchen has the monopoly of cooking for the multitude, and provides food which if fresh is not unwholesome. Unhappily, it is presented before Juggernaut, so becomes too sacred for the minutest portion to be thrown away. Under the influence of the heat it soon undergoes putrefactive fermentation, and in forty-eight hours much of it is a loathsome mass, unfit for human food. Yet it forms the chief sustenance of the pilgrims, and is the sole nourishment of thousands of beggars. Some one eats it to the very last grain. Injurious to the robust, it is deadly to the weak and wayworn, at least half of whom reach the place suffering under some form of bowel complaint. Badly as they are fed the poor wretches are worse lodged. Those who have the temporary shelter of four walls are housed in hovels built upon mud platforms about four feet high, in the center of each of which is the hole which receives the ordure of the household, and around which the inmates eat and sleep. The platforms are covered with small cells without any windows or other apertures for ventilation, and in these caves the pilgrims are packed, in a country where, during seven months out of twelve, the thermometer marks from 85 to 100 degrees Fahr. Hunter says that the scenes of agony and suffocation enacted in these hideous dens baffle description. In some of the best of them, 13 feet long by 10 feet broad and 6½ feet high, as many as eighty persons pass the night. It is not then surprising to learn that the stench is overpowering and the heat like that of an oven. Of 300,000 who visit Juggernaut in one season, 90,000 are often packed together five days a week in 5,000 of these lodgings. In certain seasons, how-

Distant View of Zempoala Aqueduct, Queretaro, Mexico

ever, the devotees can and do sleep in the open air, camping out in regiments and battalions, covered only with the same meagre cotton garment that clothes them by day. The heavy dews are unhealthy enough, but the great festival falls at the beginning of the rains, when the water tumbles in solid sheets. Then lanes and alleys are converted into torrents or stinking canals, and the pilgrims are driven into vile tenements. Cholera invariably breaks out. Living and dead are huddled together.

In the numerous so-called corpse fields around the town as many as forty or fifty corpses are seen at a time, and vultures sit and dogs lounge lazily about gorged with human flesh. In fact, there is no end to the recurrence of incidents of misery and humiliation, the horrors of which, says the Bishop of Calcutta, are unutterable, but which are eclipsed by those of the return journey. Plundered and fleeced by landlords, the surviving victims reel homeward staggering under their burden of putrid food wrapped up in dirty clothes, or packed in heavy baskets or earthenware jars. Every stream is flooded, and the travelers have often to sit for days in the rain on the banks of a river before a boat will venture to cross. At all these points the corpses

lie thickly strewn around (an English traveler counted forty close to one ferry), which accounts for the prevalence of cholera on the banks of brooks, streams and rivers. Some poor creatures drop and die by the way; others crowd into the villages and halting places on the way, where those who gain admittance cram the lodging-places to overflowing, and thousands pass the night in the streets, and find no cover from the drenching storms. Groups are huddled under the trees; long lines are stretched among the carts and bullocks on the roadside, then half saturated with the mud on which they lie, hundreds sit on the wet grass, not daring to lie down, and rock themselves to a monotonous chant through the long hours of the dreary night. It is impossible to compute the slaughter of this one pilgrimage. Bishop Wilson estimates it at not less than 50,000, and this description might be used for all the great India pilgrimages, of which there are probably a dozen annually, to say nothing of the hundreds of smaller shrines scattered through the peninsula, each of which attracts its minor horde of credulous votaries.

Such then may be accepted as a picture of one of the numerous pilgrimages made during the Dark Ages and which helped to spread infectious diseases broadcast throughout the land, polluting water supplies to such an extent that in many localities filth diseases became epidemic. It was not until about the end of the sixteenth century that general improvement began to be made in sanitary matters, although some notable exceptions may be mentioned in the construction of a few important works in Spain

Near View of Zempoala Aqueduct, Mexico

Zempoala Aqueduct. From an old print in the *Engineering News*

by the Moors, such for instance as those at Cordova in the ninth century and the repair of the Roman aqueduct at Sevilla in 1172. Until as late a date as 1183 Paris depended entirely on the River Seine for its water supply. During that year an aqueduct was constructed to conduct water to Paris from a distant source, but as late as the year 1550 the supply of water to Paris amounted to only one quart per capita per day.

London, England, was more backward than Paris in supplying the inhabitants with water, and it was not until the year 1235 that small quantities of spring water were brought to the city through lead pipes and masonry conduits.

Little is known about the strange race of people that inhabited the North American continent prior to the Indians, and it is only by the ruins of works which they constructed in the shape of mounds that their existence is known of. Nevertheless, had historians of

that time written of the engineering projects successfully carried out by the engineers of the mound builders no doubt some surprising facts would be revealed to contemporary man; for wherever men have existed, whether in China, Japan, Egypt, Europe, England or, as we are informed by astronomers, on Mars, gigantic works of irrigation have been successfully undertaken, and in most of the places mentioned conduits or aqueducts to supply water to inhabitants of communities were constructed. Reasoning then by analogy it would be safe to infer that before the race of mound builders became extinct they built works of equal importance if not of equal endurance. This belief is borne out by the fact that long before Columbus discovered America, the Aztecs of Mexico built an aqueduct to supply the ancient city, built on the site of the present City of Mexico. How long the aqueduct supplied the city before Cortez, in his expedition to conquer Mexico, destroyed the works, in 1521, nobody knows and the truth will probably never be told. The fact of the existence of such a structure is interesting chiefly as showing that in the matter of supplying communities with water the ancient tribes of Mexico and America had made considerable progress long before Europeans set foot on shore. It was in Mexico, too, that the next aqueduct in point of time was constructed. This work was built during the period between the years 1553 and 1570, under the supervision of Friar Francisco Tembleque, a Franciscan monk, and served for about two centuries to carry water from the mountain Lacayete to the city of Otumba, state of Hidalgo, district of Apan, a distance of 27.8 miles.

The aqueduct, which is known as the Zempoala, included three arched bridges of a maximum height of 124 feet. This aqueduct is further interesting from the fact that the original agreement, under which the work was performed, is still in existence, a copy of which was published in the *Engineering News*, 1888, from which the following copy is taken.

The first bridge contains forty-six arches, the second

thirteen arches and the third sixty-eight arches. The length of the longest bridge is 3,000 feet and the span of the arches at the springing line is fifty-six feet. About five years were required to build the principal part of the aqueduct which is carried on arches.

Contract Under Which Aqueduct was Built

I, Friar Cristobal y Chanriguis, preacher and secretary of this holy province of the holy evangel, certify that Father Luis Gerro, preacher and guardian of the Convent of All Saints, Zempoala, has presented to me a patent in favor of natives of said town, whose legal tenor is as follows:

We, Friar Juan De Bustamanti, Commissioner General of the Indes of the Ocean Seas, and Friar Juan De San Francisco, Provincial Master of the province of said holy evangel, and Friar Deigo Nolivarte, and Friar Juan De Gavna, and Friar Antonio Centad Rodriquez, and Friar Bernardino De Sahagun, subordinate of priests of said province of the holy evangel, declare:

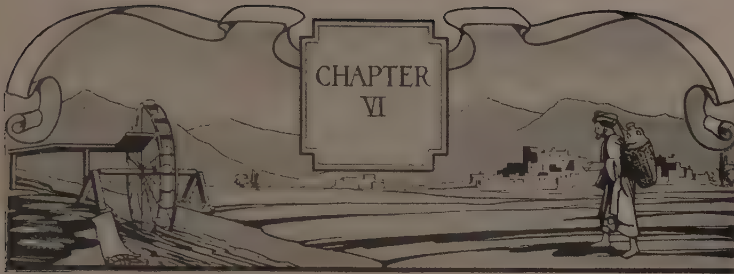
That inasmuch as you, the Governor Alcaldes and principal officers of the town of Zacoala, have agreed, for the love of God and because of our intercession, with the same officers of the town of Otumba to give to them half the water which you have in your town of Zacoala for the use and benefit of the inhabitants of Otumba and for the use of the monastery of our order founded in that town, in which you do great good to them and to our said monastery, because of our intercession as stated; and, inasmuch, moreover, as you, the said people of Zacoala, with much labor and for the good of your souls, agree to join with the people of the Flaquilpan and Zempoala in the place where you are erecting an All Saints Monastery, at which point you agree to remain and work and not to depart for the reason that you are removed from your own houses; on order to labor for the good of our souls and in return for the labor which the priests have in visiting you. And whereas now you will soon have together a monastery for the friars of our order, in which must be administered for all the holy sacraments; therefore, in return for this benefit and work we promise you that in all our time we will not cease to give friars for said monastery, and for the whole length of our lives we will aid you in your prayers in all the agreed respects; and for the time to come after our lives, in consideration of said benefit, we will petition the said Commissioners General and Provisional Masters that they will severally and collectively adhere to the agreement, and always have the charity to furnish friars in the Monastery of All Saints, as now in view of the great and good work which you have done through our intercession, both in giving the said water and in aiding the said work to supply it. And if by chance

there should happen to be so few priests that it is impossible to spare them from the house of Otumba that they shall place friars in said Monastery of All Saints first and let the loss fall upon other places than Zacoala and the Monastery of All Saints, in all of which places you are entitled to be taught by our priests.

We will beg of our successors in charity to favor us in these said respects, in return for your faithful labor and agreement in our behalf, and so we sign this agreement, made this seventh day of February, 1553.

Then followed signatures.

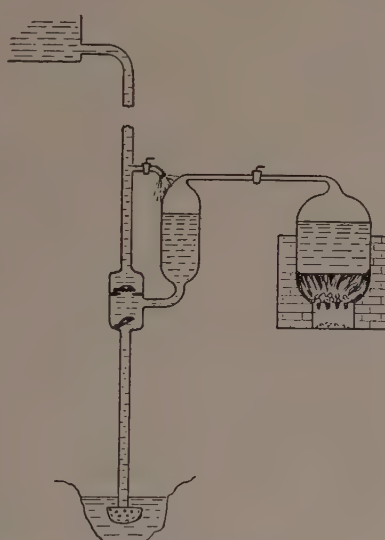
From Stereograph, copyright 1908 by Underwood & Underwood, N. Y. (See page iv)



CHAPTER VI

SYNOPSIS OF CHAPTER. Introduction of Pumping Machinery into Waterworks Practice—The Archimedes Screw—Use of Pumps in Hanover, Germany—First London Pump on London Bridge—Savery and Newcomen's Pumping Engine—The Hydraulic Ram—Pumping Engines Erected for the Philadelphia Waterworks—Pipes for Distributing Water—Hydrants and Valves for Wooden Pipes—Data regarding the Use of Wooden Pipes—Modern Pumping Engines.

WATER wheels for raising water were in use at such an early period that the exact date of their invention will never be known. The earliest known or approximate date for the invention of a water-raising machine extends back to about 215 years before the birth of Christ, when Archimedes, the Greek mathematician, who was killed at the taking of Syracuse by the Romans, invented the Archimedes screw. This apparatus, unlike pumps of later date, was operated independently of the atmospheric pressure, and by using a number of the screws in series, water could be raised to any desired height.



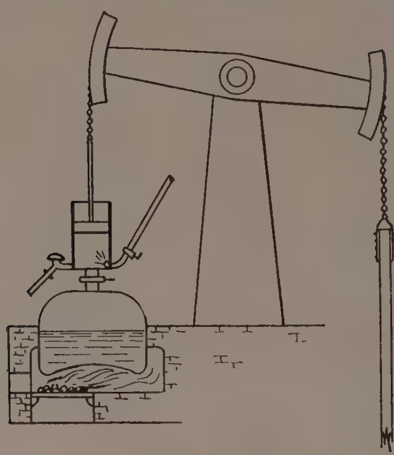
Savery's Engine

The Archimedes screw was not adapted for raising large quantities of water, however, so that Greek and Roman cities never were supplied with

water by means of engines. It remained for Hanover, Germany, to install the first pump of which we have knowledge, for supplying a town or city with water. In Germany, waterworks were constructed as early as 1412, and pumps were introduced in Hanover in the year 1527.

In London, England, the first pump was erected on the old London Bridge in 1582, for the purpose of supplying the city with water from the Thames and distributing it through lead pipes. There are only meagre accounts of the Hanover and London Bridge pumps to be had, however, and no illustrations showing their construction.

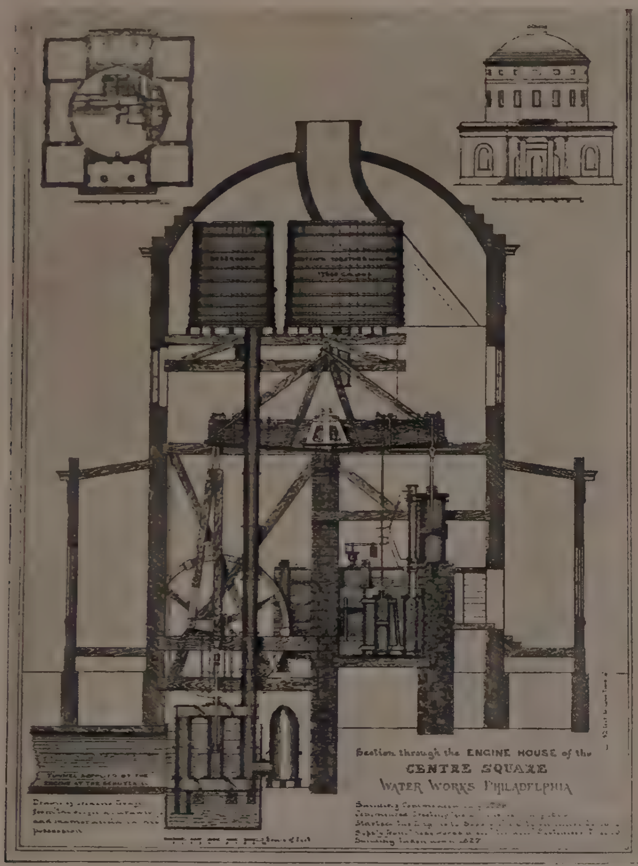
The oldest known print of a steam engine is in the Birmingham public library,* and shows a machine built in 1712 by Savery and Newcomen. A search made by *The Engineer* of London, has brought to light an old engraving dated 1725, and entitled "The Engine for Raising Water by Fire." It is unique in containing the first illustrated description of a steam engine. This machine is somewhat different from that portrayed in earlier engravings, for the boiler is fed with a portion of the hot water coming from the bottom of the cylinder or hot well. This fixes the date of the improvement described by Desagaliers in his *Experimental Philosophy* as follows: "It had been found of benefit to feed the boiler warm water coming from the top of the piston, rather than cold water, which would too much check the boiling and cause more force to be needful. But after the engine had been placed some years, some persons concerned about an engine, observing that the



Newcomen's Engine

* *Engineering Record*, Oct. 21, 1905

injected water as it came out of the induction pipe was scalding hot, when the water coming from the top of the piston was but just lukewarm, thought it would be of great advantage to feed from the induction or injected water,



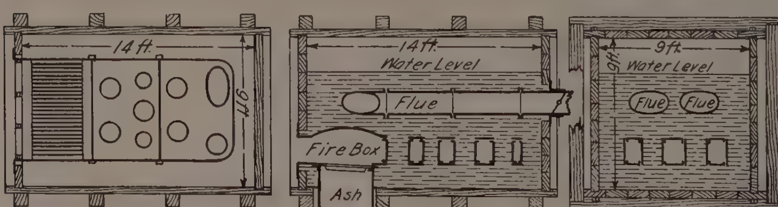
Section Through the Engine House of the Centre Square Water Works, Philadelphia

and accordingly did it, which gave a stroke or two of advantage to the engine."

At about this time or late in 1700, a Frenchman, Montgolfer, invented the hydraulic ram. This machine, while simple in construction, is one of the most efficient water-

raising devices made, and in the later improved designs amount actually to hydraulic engines. That pumping engines of this period and steam boilers to operate them were of crude design there can be no doubt, indeed, many years later, in 1800, when waterworks and a pumping station were introduced in Philadelphia, the pumps and boilers were of the crudest design. A sectional illustration of the pumping house, taken from Volume 17 of *Engineering News*, conveys a fair idea of the design of the pumps. The engine was built mostly of wood and had cylinders 6 feet long by 38¼ inches inside diameter. A double acting pump had a cylinder of 18½ inches diameter and 6-foot stroke. In these engines the lever arms, flywheel shaft and arms, flywheel bearings, the hot well, hot and cold water pumps, cold water cistern, and even the external shell of the boilers were made of wood. The boilers were rectangular chests, made of 5-inch white pine planks of the general dimensions shown in the illustration. They were braced on the sides, top and bottom with white oak scantling, 10 inches square, all bolted together with 1¼-inch iron rods passing through the planks. Inside the chest was an iron fire-box, 12 feet 6 inches long by 6 feet wide and 1 foot 10 inches deep, and 8 vertical flues, 6 of 15 inches and 2 of 12 inches diameter, through which the water circulated, the fire acting around them and passing up an oval flue situated just above the fire box and carried from the back of the boiler to near the front and then returned to the chimney at the back.

These wooden boilers were used at the Centre Street waterworks from 1801 to 1815, but did not give general

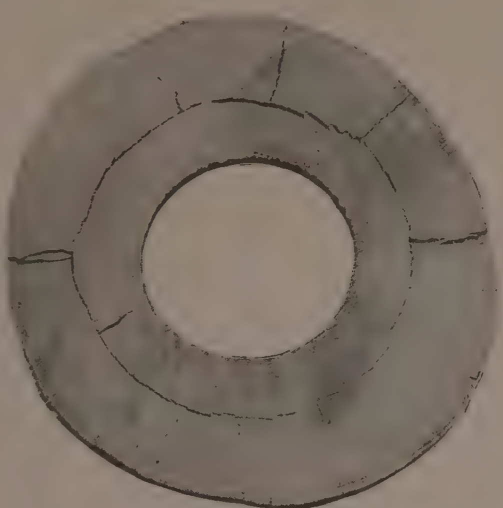


Wooden Boilers used in the Philadelphia Water Supply

satisfaction on account of the numerous leaks. They were operated at very low pressure, averaging not over 2½ pounds per square inch, but even at this extremely low pressure were found unsatisfactory.

During the early days of water supply, following the period of aqueducts, lead was the material commonly used for water supply mains. Later, however, pipes made of bored-out logs were used and continued in service up to the year 1819. The water mains used in Philadelphia were made of spruce logs, reinforced at the ends with wrought-iron bands. A section of one of these old Philadelphia water mains, which is still in a good state of preservation, is on exhibition in the Builders' Exchange of that city.

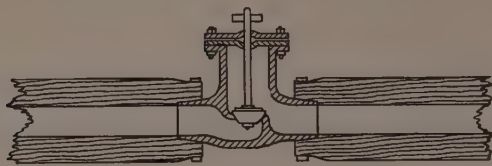
So far as is known, Philadelphia was the first city in the world to adopt cast iron pipe for water mains. Cast iron water pipes were laid in Philadelphia in the year 1804, antedating their use in London, England, by a few years.



Section of Bored-out Log Laid in Victoria, B. C., in 1862 and taken out 1900

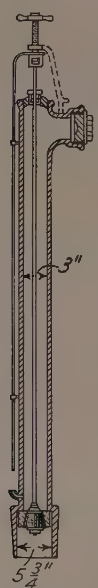
The durability of wood pipe is rather astonishing when the short life of logs exposed on the surface of the earth is considered. After lying buried in the earth for fifty or sixty years the wood pipe used in the Philadelphia waterworks was sold to Burlington, N. J., in 1804, and remained in constant use there until 1887, when larger mains were required.

Portsmouth, N. H., used bored pine logs for mains from 1798 to 1896, when they were replaced with larger



Valve for Wooden Pipes Used in the Philadelphia Water Supply

pipes. When dug up, the logs were entirely sound and good for many years' service.



Hydrant for Wooden Pipes Used in the Philadelphia Water Supply

A few data regarding the use of wooden pipes might not be without interest, while at the same time pointing out the approximate dates when waterworks were constructed in several cities. Log pipes laid in Victoria, B. C., in 1862 and taken out in 1900 were quite free from decay but badly checked.

Constantinople still receives part of its supply through wood pipe.

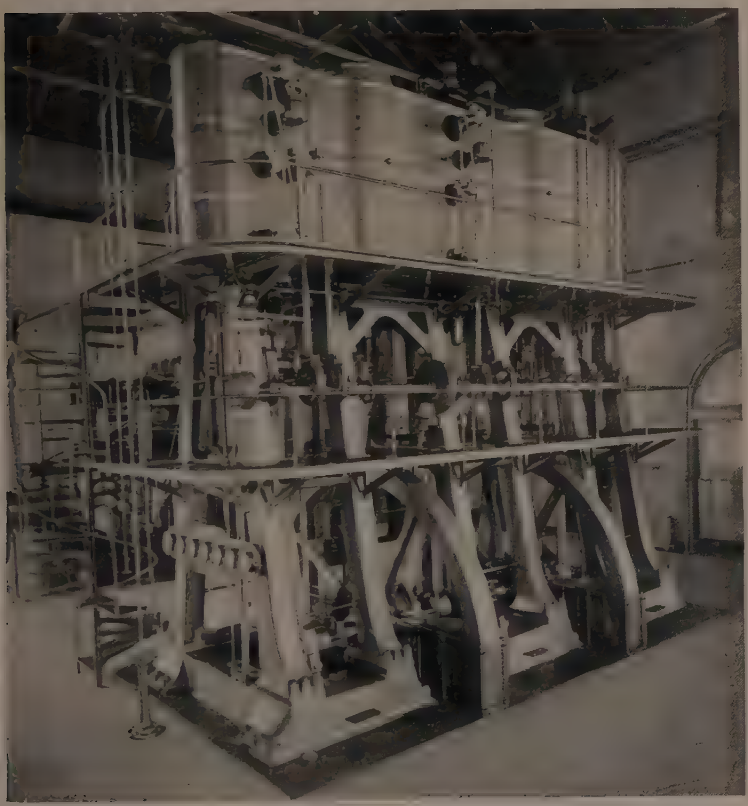
London had 400 miles of wood pipe in use for 218 years, from 1589 to 1807. When taken up it was found to be quite sound.

Boston used one system of wood pipes from 1652 to 1796, then replaced it with another one which lasted until 1848.

Denver, Colorado, has nearly 100 miles of stave pipe conduit and mains in use. All the water brought to Denver for domestic use passes through wooden pipe 37 inches in diameter, which conducts it from Cherry Creek, which is about 8 miles from center of city.

The hydrants and valves used in connection with wood pipes in Philadelphia were made of metal, and it is presumed that the valves and hydrants used in other cities were likewise made of metal.

Only one brief century has passed since waterworks pumping stations were introduced in the United States, but what wonderful improvements have been made in pumping machinery design within that short space of time! Steel and iron have taken the place of wood in the manufacture of boilers and pumps, and instead of the leaky, unsatisfactory apparatus of other days, even when working under low pressures, we now have pumping engines which will work continuously month after month under several hundred pounds pressure, and deliver the daily volumes of from a few hundred to many million gallons of water.



Modern Vertical Triple-Expansion Pumping Engine

· AQVEDVCT · CROSSING · THE · ALCANTARA · VALLEY ·
· SPANISH PORTVGVESE BORDER ·

Synopsis of Chapter. Early British Sewers—Sewer in the Great Hall of Westminster—Shape of Early English Sewers—Adoption or Recommendation of Pipe Sewers—Early Paris Sewers—Paris Sewers of To-day—Lack of Sewage Data in America—Effect of Memphis Epidemics on Sanitary Progress.

THE earliest mention we have of English sewers is contained in an old record of the fourteenth century, which informs us "The refuse from the king's kitchen had long run through the Great Hall in an open channel, to the serious injury to health and danger to life of those congregated at court. It was therefore ordered that a subterraneous conduit should be made to carry away the filth into the Thames." This description of the sewer from the Great Hall presents a vivid picture of the sewers of that day. At first the main sewers were natural water courses which, having become offensive, were arched over to shut out the sight and odor. Street gutters leading to those arched-over water courses became foul in turn, and were replaced by underground channels of the roughest brick-work or masonry. These drains which were square in cross section received and carried off slop water and rain water from the streets; the drains were constructed according to no regular design nor fixed principles, although usually they were 12 inches square and made by laying flat stones to form the bottom of the drain, then building walls of brick and topping off with flat stones, spanning from wall to wall. Excreta were collected in cesspools often built beneath the floor of the house. The introduction of the water closet about the commencement of the century, though it abated the nuisance of the latrine, aggravated

the evils of the cesspool by introducing a large volume of water far exceeding in weight the actual excreta, water-logging the subsoil. The difficulty and expense of emptying the cesspools were increased. Cesspools were therefore connected to sewers by house drains. The channels intended to carry off rain water became sewers. "Sewers and house drains were constructed on no scientific principle.* The walls were rough, irregular and porous. Naturally deposits took place in them; hand cleaning was considered a normal incident to the history of the sewer, and irrespective of the volume of sewage to be conveyed, sewers were made large enough to admit the passage of a man to facilitate cleaning."

In 1852, the General Board of Health under the Public Health Act, made their first report to the British Parliament, and advocated very strongly the introduction of smaller pipes in lieu of the large brick and stone drains then in use for house drainage. Prior to this date, the first report of the Metropolitan Sanitary Commission, London, appeared, which, while not to be taken as advocating exclusively the use of small pipes, yet pointed out the necessity of reducing the dimensions and altering the shapes of the old stone and brick structures. From this period, then, can be assumed the adoption and first use of earthenware pipes for house drains and public sewers.

The construction of sewers in Paris dates from 1663, but the earliest of those still in use are not earlier than the beginning of this century. Before the great epidemic of cholera in 1832, the total length of sewers was not more than 21 miles. The sewers of Paris to-day aggregate over 750 miles in length, and constitute one of the sights of the city. According to Mason,† "They may be inspected without charge on the first and third Wednesdays of each month in summer, by writing for a permit to the Prefect de la Seine. Descent is commonly made near the Madeleine by a substantial stairway of stone, and the boats

* Wanklyn and Cooper.

†Water Supply.

awaiting the party at the foot of the steps are fully as large and quite as comfortable as Venetian gondolas.

The great sewer, which is tunnel-like in dimensions, being 16 feet high and 18 feet broad, is, on occasions of a visit, lighted with lamps alternately red and blue, and as these stretch away into the distance the effect is decidedly striking.

Under ordinary circumstances, the sewage confines itself to the center channel, but upon occasions rises above the sidewalk on either hand. The central channel is about 10 feet wide and 4 feet deep with a curved bottom, and a walk on either side. The boats with their loads of visitors are pulled by ropes in the hands of attendants who walk along the sidewalks. On either side of the sewer may be seen the large mains, carrying the city water supply, also the telegraph cables."

Reliable data concerning the construction of sewers were not obtainable in the United States until long after the close of the Civil War. In 1857, when Julius W. Adams was commissioned to prepare plans for sewering the city of Brooklyn, N. Y., which at that time covered an area of 20 square miles, a great proportion of which was suburban territory, the engineering profession was wholly without data of any kind to guide in proportioning sewers for the drainage of cities and towns. The half century intervening since that time, however, has seen the development of sanitary engineering and witnessed the installation of sewer system, rightly proportioned and properly designed, in almost every city, town and village in the United States, while text books on engineering contain all necessary data for their design and construction. It must not be inferred from the foregoing statement that sewers were unknown in the United States prior to the construction of the Brooklyn sewer system. There was one in Boston, for example, which dated from the seventeenth century, while the first comprehensive sewerage project was designed by E. S. Chesbrough, for the city of Chicago in 1855.

There was no great activity in sewer building in this

country thirty years ago. Up to that time most of the cities were comparatively small, and no thought was given by the various municipalities to treating the combined sewage as a whole. The conditions were ripe, however, for some unusual event to crystallize public opinion and focus attention on the subject, and the event was furnished by the city of Memphis, Tennessee. Ever since 1740, Memphis had been known as a particularly unhealthful city, where the death rate was abnormally high, and epidemic after epidemic of cholera, yellow fever and other contagious diseases had scourged the inhabitants. So common had those events become, that they were accepted as incident to living in the locality, and were looked upon as special visitations which could not be avoided. Such was the state of affairs when an epidemic of yellow fever broke out in 1879, which caused a death list of 5,150, and was followed the succeeding year by a further death roll of 485, due to the scourge. Had the disease been confined within the boundaries of the city, it is possible that little would have been thought of the matter outside of the state of Tennessee. However, refugees, fleeing in all directions, carried the dread disease with them, until a strict quarantine—a shotgun quarantine—confined the infection to a certain circumscribed area. In the meantime, interference with railroad traffic, armed forces guarding the borders of neighboring states, together with the fear of the dread disease spreading all over the country, brought Congress and the public to a realization of the necessity for doing something to stamp out the disease. The most practical good accomplished by the agitation was the organization of a National Board of Health, a committee from which made a thorough examination of the sanitary conditions of Memphis. What the committee found in the way of filth was almost beyond belief. The city, they found, was honeycombed with cesspools and privy-vaults. Many of the cesspools and privy-vaults were under or in the cellars of houses, where they had been filled with accumulations and abandoned to fester and rot. Filth was everywhere—above

ground and beneath the surface, in the house and out of doors. There was only one thing to do—give the city a good cleaning; and that was the only time in history, perhaps, when pressure from the outside forced an almost bankrupt city to observe the laws of decency and sanitation.

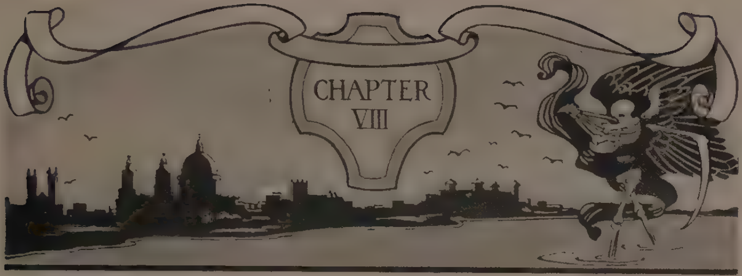
The various works which had been built up to this time to supply communities with water, had for their sole object the providing of an adequate supply so far as quantity is concerned, but gave little thought to the quality of the water, so long as it was clear and cold. The sewers or drains on the other hand were constructed solely to prevent a nuisance and with no definite knowledge that an unclean environment and polluted water were conducive to ill-health, while pure water and clean surroundings were conducive to the public health.

Some events were about to happen, however, which would awaken the public mind to the dangers of dirt, and that would usher in the present epoch of sanitation.

· BATHING · AND · BVRNING ·
· HINDV · DEAD · AT · BENARES ·

"Who dies in the waters of the Ganges obtains Heaven"

From Stereograph, copyright by Underwood & Underwood, N. Y. (See page iv)



SYNOPSIS OF CHAPTER. Sanitary Awakening—Realization of the Danger of Unwholesome Water—Cholera in London Traced to the Broad Street Pump—An Historical Stink.

TRUTH is mighty and will prevail, but sometimes it is centuries before its voice can be heard and additional centuries before its language is understood. As early as 350 B. C., Hippocrates, the Father of Medicine, pointed out the danger of unsterilized water and advised boiling or filtering a polluted water supply before drinking. He further believed that the consumption of swamp water in the raw state produced enlargement of the spleen. Had his warning been heeded the lives of millions of people who were carried to untimely graves by the scourges of pestilence which swept over Europe, Asia and Great Britain, might have been saved. Some idea of the ravage caused by filth diseases can be gained by reviewing the mortality due to cholera in London during the epidemics of 1832, 1848, 1849, 1853 and 1854.

On account of its size and lack of sanitary provisions, the London of that period was the kind of place in which, with our present knowledge of disease, we would expect a plague to reach its height. Prior to 1700, the city of London had no sewers and was without water supply, except such as was obtained from wells and springs in the neighborhood. The subsoil of London we can readily believe was foul from cesspool leachings and from slops and household refuse deposited on the surface of the ground, so that water from the wells within the city limits, while cool perhaps and palatable, could not have been

wholesome. Many public wells with pumps had been installed at certain intervals on the public highways, and an epidemic of cholera traced to one of these wells, was the means of pointing out the danger to public health, caused by an infected water supply, and of showing the

channel by which the infectious matter from people suffering from intestinal diseases was transmitted to healthy individuals. The story is well told by Sedgwick:* "One of the earliest, one of the most famous, and one of the most instructive cases of the conveyance of disease by polluted water, is that commonly known as the epidemic of Asiatic cholera connected with the Broad Street, London, well, which occurred in 1854. For its conspicuously circumscribed character, its violence and fatality, and especially

* Principles of Sanitary Science and the Public Health.

for the remarkable skill, thoroughness and success with which it was investigated, it will long remain one of the classical instances of the terrible efficiency of polluted water as a vehicle of disease.

As a monument of sanitary research, of medical and engineering interest and of penetrating inductive reasoning, it deserves the most careful study. No apology therefore need be made for giving of it here a somewhat extended account.*

The parish of St. James, London, occupied 164 acres in 1854, and contained 36,406 inhabitants in 1851. It was subdivided into three subdistricts, viz., those of St. James Square, Golden Square and Berwick Street. As will be seen by the map, it was situated near a part of London now well known to travellers, not far from the junction of Regent and Oxford Streets. It was bounded by Mayfair and Hanover Square on the west, by All Souls and Marylbone on the north, St. Anne's and Soho on the east, and Charing Cross and St. Martin's-in-the-Fields on the east and south.

In the cholera epidemics of 1832, 1848, 1849 and 1853, St. James' Parish suffered somewhat, but on the average decidedly less than London as a whole. In 1854, however, the reverse was the case. The inquiry committee estimated that in this year the fatal attacks in St. James' Parish were probably not less than 700, and from this estimate compiled a cholera death rate, during 17 weeks under consideration, of 220 per 10,000 living in the parish, which was far above the highest in any other district. In the adjoining sub-district of Hanover Square the ratio was 9; and in the Charing Cross district of St. Martin's-in-the-Fields (including a hospital) it was 33. In 1848–1849 the cholera mortality in St. James' Parish had been only 15 per 10,000 inhabitants.

Within the parish itself, the disease in 1854 was very unequally distributed. In the St. James Square district,

* The complete original report is entitled "Report on the Cholera Outbreak in the Parish of St. James, Westminster, during the Autumn of 1854. Presented to the Vestry by the Cholera Inquiry Committee, July, 1855. London, J. Churchill, 1855."

the cholera mortality was only 16 per 10,000, while in the Golden Square district it was 217 and in the Berwick Street district 212. It was plain that there had been a special cholera area, a localized circumscribed district. This was eventually minutely studied in the most painstaking fashion as to population, industries, previous sanitary history, meteorological conditions and other general phenomena common to London as a whole, with the result that it was found to have shared with the rest of London a previous long continued absence of rain, a high state of temperature both of the air and of the Thames, an unusual stagnation of the lower strata of the atmosphere, highly favorable to its acquisition of impurity, and although it was impossible to fix the precise share which each of the conditions enumerated might separately have had in favoring the spread of cholera, the whole history of that malady, as well as of the epidemic of 1854 and indeed of the plague of past epochs, justifies the supposition that their combined operation, either by favoring a general impurity in the air or in some other way, concurred in a decided manner, last summer and autumn (1854) to give temporary activity to the special causes of that disease. The inquiry committee did not, however, rest satisfied with these vague speculations and conclusions, but as previously shown in the history of this local outbreak, the resulting mortality was so disproportioned to that in the rest of the metropolis and more particularly to that in the immediately surrounding districts, that we must seek more narrowly and locally for some peculiar conditions, which may help to explain this serious visitation.

Accordingly special inquiries were made within the district involved in regard to its elevation of site, soil and subsoil, including an extended inquiry into the history of a pest field said to have been located within this area in 1665, 1666, to which some had attributed the cholera of 1854; surface and ground plan; streets and courts; density of population; character of the population; dwelling houses; internal economy as to space, light, ventilation and

general cleanliness; dust bins and accumulations in yards, cellars and areas; cesspools, closets and house drains; sewers, their water flow and atmospheric connection; public water supply and well water supply. No peculiar condition or adequate explanation of the origin of the epidemic was discovered in any of these, even after the most searching inquiry, except in the well water supply. Abundant general defects were found in the other sanitary factors, but nothing peculiar to the cholera area, or if peculiar, common to those attacked by the disease, could be found excepting the water supply.

At the very beginning of the outbreak, Dr. John Snow, with commendable energy, had taken the trouble to get the number and location of the fatal cases, as is stated in his own report:

"I requested permission, on the 5th of September, to take a list, at the general register office, of the deaths from cholera registered during the week ending the 22d of September, in the subdistricts of Golden Square and Berwick Street, St. James' and St. Anne's, Soho, which was kindly granted. Eighty-nine (89) deaths from cholera were registered during the week in the three subdistricts, of these only six (6) occurred on the first four days of the week, four occurred on Thursday, August 31, and the remaining 79 on Friday and Saturday. I considered therefore that the outbreak commenced on the Thursday, and I made inquiry in detail respecting the 83 deaths registered as having taken place during the last three days of the week.

On proceeding to the spot I found that nearly all the deaths had taken place within a short distance of the pump in Broad Street. There were only ten deaths in houses situated decidedly nearer to another street pump. In five of these cases the families of the deceased persons told me that they always sent to the pump in Broad Street, as they preferred the water to that of the pump which was nearer. In three other cases the deceased were children who went to school near the pump in Broad Street. Two of them

were known to have drunk the water and the parents of the third think it probable that it did so. The other two deaths beyond the district which the pump supplies, represent only the amount of mortality from cholera that was occurring before the eruption took place.

With regard to the 73 deaths occurring in the locality belonging, as it were, to the pump, there were 61 instances in which I was informed that the deceased persons used to drink the water from the pump in Broad Street, either constantly or occasionally. In six (6) instances I could get no information, owing to the death or departure of every one connected with the deceased individuals; and in six (6) cases I was informed that the deceased persons did not drink the pump water before their illness.

The result of the inquiry consequently was that there had been no particular outbreak or increase of cholera in this part of London, except among the persons who were in the habit of drinking the water of the above mentioned pump well.

I had an interview with the Board of Guardians of St. James' Parish on the evening of Thursday, 7th of September, and represented the above circumstances to them. In consequence of which the handle of the pump was removed on the following day.

The additional facts that I have been able to ascertain are in accordance with those related above, and as regards the small number of those attacked, who were believed not to have drunk the water from the Broad Street pump, it must be obvious that there are various ways in which the deceased persons may have taken it without the knowledge of their friends. The water was used for mixing with spirits in some of the public houses around. It was used likewise at dining rooms and coffee shops. The keeper of a coffee shop which was frequented by mechanics and where the pump water was supplied at dinner time, informed us on the 6th of September that she was already aware of nine of her customers who were dead."

On the other hand, Dr. Swan discovered that while a

workhouse (almshouse) in Poland Street was three-fourths surrounded by houses in which cholera deaths occurred, out of 525 inmates of the workhouse, only five cholera deaths occurred. The workhouse, however, had a well of its own in addition to the city supply, and never sent for water to the Broad Street pump. If the cholera mortality in the workhouse had been equal to that in its immediate vicinity, it would have had 50 deaths.

A brewery in Broad Street employing seventy workmen was entirely exempt, but having a well of its own, and allowances of malt liquor having been customarily made to the employees, it appears likely that the proprietor was right in his belief that resort was never had to the Broad Street well.

It was quite otherwise in a cartridge factory at No. 38 Broad Street, where about two hundred work people were employed, two tubs of drinking water having been kept on the premises and always filled from the Broad Street pump. Among these employees eighteen died of cholera. Similar facts were elicited for other factories on the same street, all tending to show that in general those who drank the water from the Broad Street pump well suffered either from cholera or diarrhœa, while those who did not drink that water escaped. The whole chain of evidence was made absolutely conclusive by several remarkable and striking cases, like the following:

"A gentleman in delicate health was sent for from Brighton to see his brother at No. 6 Poland Street, who was attacked by cholera and died in twelve hours, on the 1st of September. The gentleman arrived after his brother's death, and did not see the body. He only stayed about twenty minutes in the house, where he took a hasty and scanty luncheon of rump steak, taking with it a small tumbler of cold brandy and water, the water being from Broad Street pump. He went to Pentonville, was attacked with cholera on the evening of the following day, September 2d, and died the next evening.

The death of Mrs. E. and her niece, who drank the

water from Broad Street at the West End, Hampstead, deserves especially to be noticed. I was informed by Mrs. E.'s son that his mother had not been in the neighborhood of Broad Street for many months. A cart went from Broad Street to West End every day, and it was the custom to take out a large bottle of the water from the pump in Broad Street, as she preferred it. The water was taken out on Thursday, the 31st of August, and she drank of it in the evening and also on Friday. She was seized with cholera on the evening of the latter day, and died on Saturday. A niece who was on a visit to this lady also drank of the water. She returned to her residence, a high and healthy part of Islington, was attacked with cholera, and died also. There was no cholera at this time either at West End or in the neighborhood where the niece died. Besides these two persons only one servant partook of the water at West End, Hampstead, and she did not suffer, at least not severely. She had diarrhœa."

Dr. Snow's inquiry into the cases of cholera which were nearer other pumps showed that in most the victims had preferred, or had access to, the water of the Broad Street well, and in only a few cases was it impossible to trace any connection with the pump. Finally, Dr. Snow made a statistical statement of great value which is here given in its original form:

The Broad Street, London, Well and Deaths from Asiatic Cholera near it in 1854

Date	Number of Fatal Attacks	Deaths
August 19 . . .	1	1
August 20 . . .	1	0
August 21 . . .	1	2
August 22 . . .	0	0
August 23 . . .	1	0
August 24 . . .	1	2
August 25 . . .	0	0
August 26 . . .	1	0
August 27 . . .	1	1
August 28 . . .	1	0

Date	Number of Fatal Attacks	Deaths
August 29 . . .	1	1
August 30 . . .	8	2
August 31 . . .	56	4
September 1 . . .	143	70
September 2 . . .	116	127
September 3 . . .	54	76
September 4 . . .	46	71
September 5 . . .	36	45
September 6 . . .	20	37
September 7 . . .	28	32
September 8 . . .	12	30
September 9 . . .	11	24
September 10 . . .	5	18
September 11 . . .	5	15
September 12 . . .	1	6
September 13 . . .	3	13
September 14 . . .	0	6
September 15 . . .	1	8
September 16 . . .	4	6
September 17 . . .	2	5
September 18 . . .	3	2
September 19 . . .	0	3
September 20 . . .	0	0
September 21 . . .	2	0
September 22 . . .	1	2
September 23 . . .	1	3
September 24 . . .	1	0
September 25 . . .	1	0
September 26 . . .	1	2
September 27 . . .	1	0
September 28 . . .	0	2
September 29 . . .	0	0
September 30 . . .	0	0
Date unknown . . .	45	0
	616	616

In addition to the original and general inquiry conducted from the time of the outbreak by Dr. Snow, the Rev. H. Whitehead, M. A., curate of St. Luke's in Berwick Street, and like Dr. Snow, a member of the Cholera Inquiry Committee, whose knowledge of the district both before and during the epidemic, owing to his official position, gave him unusual advantages, made a most elaborate and painstaking house-to-house investigation of one of the principal streets affected, viz., Broad Street itself.

The Rev. H. Whitehead's report, like that of Dr. Snow,

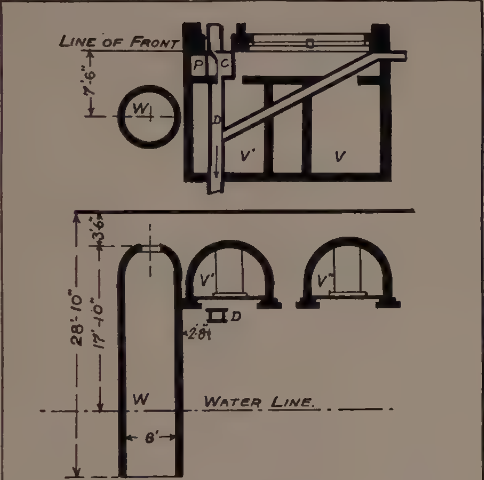
is a model of careful and extended observation and study, cautious generalizing and rigid verification. It is an excellent instance of inductive scientific inquiry by a layman in sanitation. Mr. Whitehead found the number of houses on Broad Street 49; the resident householders 35; the total number of resident inhabitants 896; the total number of deaths among these 90. Deaths among non-residents (workmen, etc.) belonging to the street, 28. Total deaths chargeable to this street alone, 118. Only 10 houses out of 49 were free from cholera.

The dates of attack of the fatal cases resident in this single street were as follows:

Date of Attack	Number of Fatal Attacks
August 12	1
August 28	1
August 30	1
August 31	6
September 1	26
September 2	24
September 3	9
September 4	8
September 5	6
September 6	5
September 7	0
September 8	2
September 9	1
	90

Mr. Whitehead's detailed investigation was not made until the spring of 1855, but in spite of this fact it supplied most interesting and important confirmatory evidence of Dr. Snow's theory that the Broad Street well was the source of the epidemic. Mr. Whitehead, moreover, went further than Dr. Snow, and endeavored to find out how the well came to be infected, why its infectious condition was so limited, as it appeared to have been, and to answer various other questions which occurred in the course of his inquiry. As a result, he concluded that the well must have been most infected on August 31st, that for some

reason unknown a partial purification began on September 2d, and thereafter proceeded rapidly. There was some evidence that on August 30th the water was much less infected than on the 31st, so that its dangerous condition was apparently temporary only. He further discovered that in the house No. 40 Broad Street, which was the nearest house to the well, there had been not only four fatal cases of cholera contemporaneous with the epidemic, but certain earlier cases of an obscure nature, which might have been cholera, and that dejecta from these had been thrown without disinfection into a cesspool very near the well. On his reporting these facts in April, 1855, to the main committee, Mr. J. York, secretary and surveyor to the committee, was instructed to survey the locality and examine the well, cesspool and drains at No. 40 Broad Street. Mr. York's report revealed a startling condition of affairs. The well was circular in section, 28 feet 10 inches deep, 6 feet in diameter, lined with brick, and when examined contained 7 feet 6 inches of water. It was arched in at the top, dome fashion, and tightly closed at a level 3 feet 6 inches below the street by a cover occupying the crest of the dome. The bottom of the main drain of the house No. 40 Broad



ASIATIC CHOLERA
—AND—
THE BROAD STREET WELL.
LONDON 1854.
W_ _ _ _WELL
D_ _ _ _MAIN DRAIN OF HOUSE NO. 40.
V' AND V"_CELLARS UNDER STREET.
C_ _ _ _CESSPOOL.
P_ _ _ _ PRIVY.
(AFTER MR. YORK'S ORIGINAL DRAWINGS.)

Street, lay 9 feet 2 inches above the water level, and one of its sides was distant from the brick lining of the well only 2 feet 8 inches. It was constructed on the old fashioned plan of a flat bottom, 12 inches wide, with brick sides rising about 12 inches high, and covered with old stones. As this drain had but a small fall or inclination outward to the main sewer, the bottom was covered with an accumulation of soil deposit about 2 inches thick, and upon clearing this soil away the mortar joints of the old stone bottom were found to be perished, as was also all the jointing of the brick sides, which had brought the brickwork into the condition of a sieve, and through which the house drainage water must have percolated for a considerable period.

After opening back the main drain, a cesspool, intended for a trap but misconstructed, was found in the area, 3 feet 8 inches long by 2 feet 6 inches wide and 3 feet deep, and upon or over a part of this cesspool a common open privy, without water supply, for the use of the house, was erected, the cesspool being fully charged with soil. This privy was formed across the east end of the area, and upon removing the soil the brickwork of the cesspool was found to be in the same decayed condition as the drain, and which may be better comprehended by stating that the bricks were easily lifted from their beds without the least force, so that any fluid could readily pass through the work, or as was the case when first opened, over the top course of bricks of the trap into the earth or made ground, immediately under and adjoining the end wall eastward, this surface drainage being caused by the accumulation of soil in, and the misconstruction of, the cesspool.

Thus, therefore, from the charged condition of the cesspool, the defective state of its brickwork and also that of the drain, no doubt remains in my mind that constant percolation for a considerable period had been conveying fluid matter from the drains into the well; but lest any doubt should arise on this subject hereafter, I had two spaces of the brick stemming, 2 feet square each, taken out

of the inside of the well, the first 13 feet deep from the level of the street paving, the second 18 feet deep, and a third was afterward opened still lower, when the washed appearance of the ground and gravel fully corroborated the assumption. In addition thereto, the ground was dug out between the cesspool and the well to 3 feet below the bottom of the former, and its black, saturated, swampy condition clearly demonstrated the fact, as did also the small furrowed appearance of the underlying gravel observed from the inside of the well, from which the fine sand had been washed away during the process of filtration. It was thus established as clearly as can be done by circumstantial evidence, that the great epidemic in St. James' Parish, Westminster, London, in 1854, was caused by the polluted water of the Broad Street well, which for a very few days was probably infected with cholera germs. It is much less clear how the well became infected, but it seems probable that the dejecta of a cholera patient found tolerably direct access to the well from the cesspool or drain of a house nearby. There is no evidence whatever that the germs multiplied in the well, but rather much evidence that they rapidly died out. It is repeatedly stated in the report that the water was preferred for drinking because it was cold, *i. e.*, colder than the cistern water derived from public water supply and this condition would probably favor such dying out.

That the water had long been polluted there can be no doubt. There was evidence of this, and also some evidence that it was worse than usual at the time when it was probably infected. One consumer spoke of it as having been at the time offensive in taste and odor. It is instructive to note that mere pollution seems to have done no obvious harm. Specific infection, however, produced Asiatic cholera.

Mr. Whitehead in his singularly fair and candid report raises an interesting question, viz: Why, if an early and unrecognized case in the house in question brought about infection of the well, should not the four severer cases of

undoubted cholera subsequently in the same house, with no known change in the drainage, have produced even greater disaster? This question remains unanswered, except that after the removal of the pump handle on the 8th of September access to the well was shut off, and during the intermediate week the well may have been avoided by the frightened people; or owing to illness less water may have been used in No. 40 Broad Street, so that the cesspool did not overflow, or some other condition unknown may have been changed."

Following closely on the heels of the report of the Cholera Inquiry Commission came an event, which, though fraught with no danger, nevertheless did more to call attention of people in general and lawmakers in particular to the necessity for sanitary surroundings and the danger of polluted water supply, than had all the epidemics of cholera and typhoid fever which had preceded. This event was one of the most famous stinks recorded, if not the most famous, and arose from the Thames in London in 1858 and 1859. The following account of this historic stink is by Dr. Budd.*

"The need of some radical modification in the view commonly taken of the relation which subsists between typhoid fever and sewage was placed in a very striking light by the state of the public health in London during the hot months of 1858 and 1859, when the Thames stank so badly. The late Dr. McWilliam pointed out at the time, in fitting and emphatic terms, the utter inconsistency of the facts with the received notion of the subject. Never before had nature laid down the data for the solution of a problem of this kind in terms so large, or wrought them out to so decisive an issue. As the lesson then taught us seems to be already well nigh forgotten, I may perhaps be allowed to recall some of its most salient points.

The occasion, indeed, as has already been hinted, was no common one. An extreme case, a gigantic scale in the phenomena, and perfect accuracy in the registration of the

* *Typhoid Fever, its Nature, Mode of Spreading and Prevention.*

results—three of the best of all the guarantees against fallacy—were combined to make the inductions sure. For the first time in the history of man, the sewage of nearly three millions of people had been brought to seethe and ferment under a burning sun, in one vast open cloaca lying in their midst. The result we all know. Stench so foul we may well believe had never before ascended to pollute this lower air. Never before at least had a stink risen to the height of an historic event. Even ancient fable failed to furnish figures adequate to convey a conception of its thrice-Augean foulness. For many weeks the atmosphere of Parliamentary committee rooms was only rendered barely tolerable by the suspension before every window of blinds saturated with chloride of lime, and by the lavish use of this and other disinfectants. More than once, in spite of similar precautions, the law courts were suddenly broken up by an insupportable invasion of the noxious vapor. The river steamers lost their accustomed traffic, and travelers pressed for time often made circuit of many miles rather than cross one of the city bridges.

For months together the topic almost monopolized the public prints. Day after day, week after week, the *Times* teemed with letters filled with complaint, prophetic of calamity or suggesting remedies. Here and there a more than commonly passionate appeal showed how intensely the evil was felt by those who were condemned to dwell on the Stygian banks. At home and abroad the state of the chief river was felt to be a national reproach. "India is in Revolt, and the Thames Stinks," were the two great facts coupled together by a distinguished foreign writer to mark the climax of a national humiliation. But more significant still of the magnitude of the nuisance was the fact that five million pounds in money were cheerfully voted by a heavily-taxed community to provide the means for its abatement. With the popular views as to the connection between epidemic disease and putrescent gases, this state of things naturally gave rise to the worst forebodings.

Members of Parliament and noble lords, dabblers in

sanitary science, vied with professional sanitarians in predicting pestilence. If London should happily be spared the cholera, decimation by fever was at least a certainty. The occurrence of a case of malignant cholera in the person of a Thames waterman, early in the summer, was more than once cited to give point to these warnings, and as foreshadowing what was to come. Meanwhile the hot weather passed away; the returns of sickness and mortality were made up, and, strange to relate, the result showed not only a death rate below the average, *but as the leading peculiarity of the season*, a remarkable diminution in the prevalence of fever, diarrhœa and the other forms of disease commonly ascribed to putrid emanations."

While the historical stink of the Thames was without apparent effect on the public health, the nuisance caused was so great and the fear engendered was so real, that much good was the immediate result. One of the most lasting and far reaching benefits was the appointment by Parliament of a Rivers Pollution Commission, to study into and devise ways for the prevention of pollution of streams, lakes and water-sheds, from which public water supplies are obtained. In addition to this, the stink stimulated inquiry into the sources of infection in cases of epidemic diseases, and means for preventing the spread of disease, with such success, that as early as 1866 it was decided that cholera was a water-borne disease and that the cause of infection, whatever it was, could be destroyed by heat. This is evidenced by the signs the local sanitary authorities caused to be issued during the epidemic of Asiatic cholera in 1866:

CHOLERA NOTICE!

"The inhabitants of the district within which cholera is prevailing are earnestly advised *not to drink any water which has not been boiled.*"

Following this, the Rivers Pollution Commission* of 1868 went on record as authority for the statement that

* *Sixth Report*, London, 1874.

"the existence of specific poison capable of producing cholera and typhoid fever is attested by evidence so abundant and strong as to be practically irresistible. These poisons are contained in the discharges from the bowels of persons suffering from these diseases." So it was that close observation and rigid inquiry discovered the truths that discharges from bowels of persons suffering from intestinal diseases contain the specific poison of the disease; that these discharges, mixed with the sewage of cities, often found their way into water supplies, and thus caused an epidemic of the same disease, and that boiling of water before drinking would destroy the infection, thus rendering it harmless. These truths stand to-day and the same means of prevention are resorted to in time of danger that were recommended during the epidemic of cholera in London in 1866. We know now, however, thanks to the investigations of Louis M. Pasteur, that all that class of disease which he designated as zymotic, are caused by little microscopic vegetation which gain lodgment in the body where they grow, multiply and thrive at the expense of the host; and knowing the specific cause of a disease makes it more easy to fight to prevent and to cure.

· THE · FOVNTAIN · OF · ELISHA ·
· NEAR · JERICHO, · PALESTINE ·

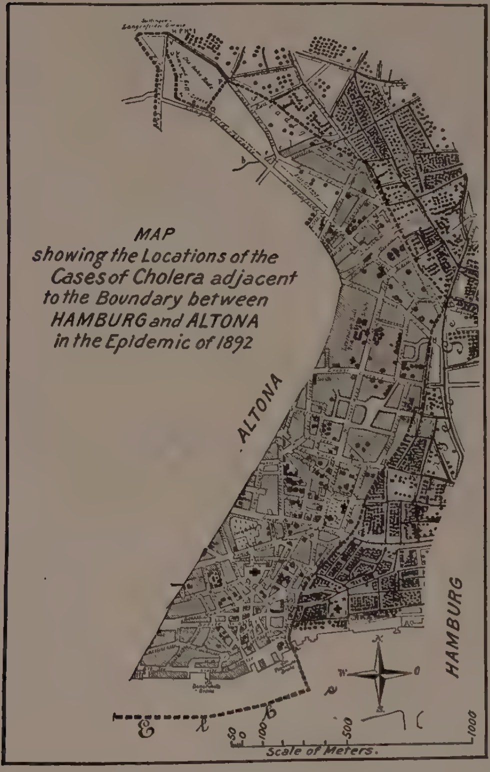
From Stereograph, copyright 1899 by Underwood & Underwood, N. Y. (See page iv)

SYNOPSIS OF CHAPTER. Introduction of Water Filters—Striking Example of their Efficiency and Value—Cholera at Altona and Hamburg—Purification of Sewage—The Automatic Scavenger of Mouras—Investigations of the Massachusetts State Board of Health—Garbage Destruction.

AS the suburban population around London, England, grew and occupied the drainage area from which the London water supply was obtained, just in such proportion was the water supply polluted, and London was early forced to devise measures for purifying an already polluted water; so it is that as early as 1839 London was filtering part of the water derived from surface sources, and so successful were the early attempts that at the present time although London is supplied with water by eight separate water companies, all of the water used within its confines which is derived from rivers, lakes or streams, is filtered before delivery into the distributing mains. Europe was not slow to grasp the value of filtration, and at the present time most cities of importance in Continental Europe have slow sand filters, while America, or at least the United States, which is reputed to adopt almost immediately anything which possesses merit, had constructed no filters as late as 1880, and to-day can number but few. A striking illustration of the value of filtration for sterilizing an infected water supply can be instanced in the cholera epidemic of Hamburg, Germany.

On the river Elbe, some miles from the sea, there are three cities adjoining and forming in appearance one large city of 800,000 inhabitants, the combined sewage of which is discharged into the river Elbe. The water supply to the

city of Hamburg, a free German city, with a population of 640,400, is derived from the Elbe above where the sewage is discharged into the river but not sufficiently far away to escape contamination from a recision of polluted water at flood tide. This water after some imperfect sedimentation passes direct to the consumer without filtration. The supply of water to Wandsbeck, a city of 20,000 population, is obtained from a lake which is unexposed to contamination and is filtered before being delivered to the mains. The supply to Altona, on the other hand, a Prussian city of 143,000 inhabitants, is obtained from the river Elbe at a point about 8 miles below where it receives the combined sewage of the three cities, with their population of over 800,000. It will thus be seen that the source of supply to Altona is the worst of the three. This most grossly polluted supply, however, is filtered with exceeding care before delivery to the consumers, and to this fact is attributed the freedom from cholera that visited Hamburg in



Boundary line indicated by line of dashes.
Cases of cholera by solid circles.
Cases of cholera imported from Hamburg by circles.
Water mains in Hamburg streets by black lines.

1892. The story is well told by Dr. Thorne, medical officer of the London Local Government Board.*

"The different behavior of Hamburg and Altona as regards cholera is extremely interesting. The two towns adjoin; they are practically one city. The division between the two is no more obvious than that between two densely peopled London parishes, and yet a spot map indicating the houses which were attacked with cholera, which was shown to me by Professor Koch, points out clearly that whereas the disease prevailed in epidemic form on the Hamburg side of the boundary line, that line running in and out among the streets and houses and at times passing diagonally through the houses themselves, formed the limit beyond which the epidemic, as such, did not extend. The dots on one side of the dividing line were proof of the epidemicity of cholera in Hamburg, their comparative absence on the Altona side of it was proof of the absence of the epidemic in Altona. To use Professor Koch's own words: 'Cholera in Hamburg went right up to the boundary of Altona and then stopped. In one street, which for a long way forms the boundary, there was cholera on the Hamburg side, whereas on the Altona side was free from it, and yet there was one detectable difference, and one only, between the two adjacent areas—they had different water services.' Professor Koch has collected certain proofs which he regards as crucial on this point, and Dr. Reincke has supplied me with a small plan in support of the contention. At one point close to and on the Hamburg side of the boundary line between Hamburg and Altona, is a large yard, known as the Hamburger-Platz. It contains two rows of large and lofty dwellings, containing 72 separate tenements and some 400 people, belonging almost wholly to those classes who suffered most from cholera elsewhere in Hamburg. But while cholera is shown by the spot map to have prevailed all around, not a single case occurred among the many residents of this court during the whole epidemic. And why? Professor Koch explains that

* *Cholera Prospects and Prevention.*

owing to local difficulties, water from the Hamburg mains could not easily be obtained for the dwellings in question, and hence a supply had been laid in from one of the Altona mains in an adjacent street. This was the only part of Hamburg which received Altona water, and I am informed that it was the only spot in Hamburg in which was aggregated a population of the class in question, which escaped the cholera. At the date of my visit to Hamburg, a notice board was affixed at the entrance to this court. It stated that certain tenements were to let; but, above all, in large type, and as an inducement to intending tenants, was the announcement that the court was not only within the jurisdiction of Hamburg, with the privileges still attaching to the old Hanseatic cities, but that it had a supply of Altona water.

During the epidemic the deaths in the several cities were:

	Population	Deaths	Deaths per 10,000 Inhabitants
Hamburg	640,000	8,605	134.4
Altona	143,000	328	23.0
Wandsbeck	20,000	43	22.0

That infectious matter was communicated to the Elbe water from Hamburg is not in any way a hypothesis. Cholera germs had been as a fact found in the Elbe water. They were found a little below the place where the Hamburg main sewer flows into the Elbe. They were also found in one of the two Altona basins into which the water flowed before filtration."

No more striking example could be found, demonstrating on a large scale the efficiency of filtration as a preventive of water-borne diseases than that of the cholera epidemic of Hamburg in 1892, yet, at the present writing, there are people holding public offices throughout the United States who do not believe in the value of filtration as a public prophylactic, or who are so indifferent as not to

advocate its adoption. Nor is this disbelief confined to public officials; many there are outside of public office who have made no study of sanitation and cannot believe that merely passing water downward through sand will purify it, and for the benefit of those who wish to be better informed, the story of the Hamburg epidemic of cholera, together with the part played by filters in saving Altona from a worse visitation, cannot be too often told.

It is but natural that, suspicion having once fallen on water as a source or vehicle of disease, means would be adopted not only to properly sterilize water before delivering it to the public, but, furthermore, to select the source of supply where there was least danger of contamination from filth. By this time public water supplies had progressed to such a stage that but few towns, cities or villages of any importance were without a municipal plant. Further, most cities of any importance had a more or less complete system of sewers, and the filth from these sewers was discharging freely, and in the crude state, into the streams and rivers of the realm. Such a condition of affairs could not last long without causing a nuisance, as well as becoming a menace to the health of the commonwealth, and it was not long before the problem was discussed of purifying the sewage before discharging it into streams and rivers. In Great Britain, the pollution of streams was felt more keenly than in America. The population along the rivers in Great Britain is quite dense, and the rivers, which are comparatively small, are used as sources of supply for the different municipalities along the banks, so that some means had to be devised to prevent the people up stream from polluting and perhaps infecting it for those lower down. So early as 1840, this matter forced itself on the attention of Parliament, and in 1843, a royal commission, the Health of Towns Commission, was appointed to inquire into the present state of large towns and populous districts. This was followed in 1857 by the Sewage of Towns Commission, a royal commission appointed to inquire into the best means of distributing the sewage of towns, and in 1865

by the Rivers Pollution Commission, a royal commission appointed to inquire into the best means of preventing the pollution of rivers.

Progress was not at a standstill during this time, however, but, on the contrary, chemical precipitation of sewage and purification by the application to land were striving with each other for supremacy. Up to that time, the important part that bacteria play in the reduction of organic matter was not understood, and instead of affording every advantage for the decomposition and fermentation of organic matter under the least objectionable conditions, the principal efforts of those interested in the problem were to prevent or put off as long as possible the septic action of sewage. It was not until so late as the year 1880 that attention was turned toward the possibility of the micro-organisms in sewage. In that year Dr. Mueller took out a patent endeavoring to utilize the micro-organism in sewage for the purpose of purification. According to Dr. Mueller's views, "The contents of sewage are chiefly of organic origin, and in consequence of this an active process of decomposition takes place in sewage through which the organic matters are dissolved into mineral matters, or, in short, are mineralized, and thus become fit to serve as food for plants. To the superficial observer, however, it is chiefly a process of digestion, in which the various, mostly microscopically small, animal and vegetable organisms utilize the organically fixed power for their life purpose.

"The decomposition of sewage in its various stages is characterized by the appearance of enormous numbers of spirilla, then of vibrios (swarming spores) and, finally, of moulds. At this stage commences the reformation of organic substance with the appearance of chlorophyl-holding protococcus."

About the same time, December, 1881, the account of Mouras's automatic scavenger was published in France. Mouras had been working and experimenting along the same lines as Dr. Mueller, and the result was an apparatus consisting of a closed vessel or vault, with a water seal

which rapidly changed excrementatious matter into a homogeneous fluid, only slightly turbid, and holding the solid matters in suspension in the form of scarcely visible filaments. The principle claimed for his automatic scavenger by Mouras was that animal dejecta within themselves contained all the principles of fermentation necessary to liquefy them.

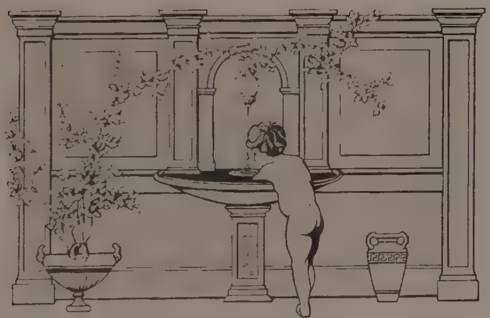
The teachings of Dr. Mueller and Mouras went unheeded for a long time, on account of the chemical processes then in vogue. It was maintained by those who were supposed to know, that lime and other antiseptic substances were particularly valuable in sewage purification, because they destroyed living organisms, such as bacteria, which give rise to putrefaction and fermentation. They contended that if all the organisms could be destroyed, that sewage would be rendered unobjectionable. So conditions stood when in January, 1887, Mr. Dibden read a paper before the Institute of Civil Engineers, in which he pointed out that the very essence of sewage purification was not the destruction of bacterial life, but the resolution of organic matter into other combinations by the agency of the micro-organisms. He pointed out, further, that a septic and not an antiseptic action was what was wanted, consequently any process which arrested the activity of the bacteria was the reverse of what was desired. Dibden's paper had the effect of turning investigation in the right direction, but a world of experimenting on a practical scale would be necessary before the practice of sewage purification could be established on a safe, sound and scientific footing. It remained for the Massachusetts State Board of Health to conduct those investigations, and so thoroughly was it accomplished that the records of their experiments furnish the basis for sewage purification practice in the United States. The experiments have been carried on since 1887, and the thoroughness and value of these investigations can be judged by the fact that during one period of twenty-two months four thousand chemical examinations were made in addition to the microscopic examinations.

Following the historic investigations of the Massachusetts State Board of Health, numerous engineers and investigators commenced applying to practice the principles there laid down, and with such good results that there are upwards of 200 purification plants in the United States today, and in Pennsylvania alone plans are under way at the present time for over one hundred sewage disposal works. Such a showing is encouraging, and leads to the hope that within a decade no city of any importance within the States will be pouring impurified sewage into public streams or lakes.

Up to within the last quarter century no thought was given in the United States to the disposal or destruction of the grosser particles which make up the waste of a large city, nor was provision made at sanatoria, hospitals and like institutions for the destruction of materials which might prove infectious; yet, no less important than the removal of sewage by water carriage is the systematic collection and subsequent destruction of all matter of no value which might prove a vehicle of disease, if a clean, sanitary environment is to be maintained. The necessity for such removal and destruction was first felt in hospitals, sanatoria, barracks and camps, where many people are brought together under unusual circumstances, and infective matter is liable to accumulate, thereby proving a menace to the community. It is not surprising, therefore, that the desirability of destroying such accumulated wastes was first brought home to the medical staff connected with military service, and that the medical authorities should be connected with the British army.

The first garbage destructor, or garbage furnace, of which there is any record, was constructed about 1860, at Gibraltar, for the exclusive destruction by fire of all waste matter from the British garrison. In the United States, likewise, it was at the army posts where the need for waste destructors was first felt, and in 1885 Lieutenant H. I. Reilly, U. S. A., built the first American garbage furnace at Governor's Island, New York Harbor. From that time

on, the value of garbage destructors became more widely known, and within recent years the need for a sanitary and convenient method for disposing of waste matters has been occupying the attention of those in charge of institutions devoted to the care of the sick, infirm, feeble, and to the control of the criminal. In addition to the superintendents of hospitals, prisons, sanatoria and asylums, those in charge of medical schools and laboratories, hotels, business houses and municipalities have given the matter much consideration, and at the present time most of the large cities of the United States have constructed garbage destructors, or are seriously considering the step, while the principal hospitals, hotels, department stores, medical colleges and public institutions throughout the country have already installed destructors. Likewise, garbage destructors have been constructed at all of the United States Government army posts.



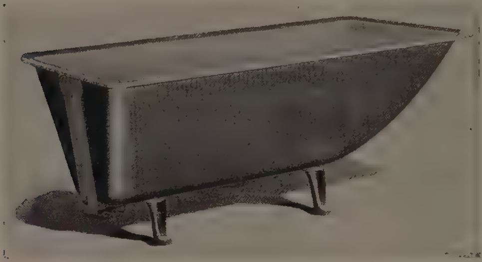
The Twenty-third Street Public Bath is considered one of the finest and most modern in New York City

Passing of the Marble Lavatory—Public Bath Houses—Public Wash Houses—Public Comfort Stations—Conclusion

NO history of sanitation would be complete without touching upon the plumbing fixtures in buildings, and showing the marked progress along these lines within the last quarter of a century. It is only a little over a century and a quarter since the first English patent was granted for a water closet. That was in the year 1775, and was issued to Alexander Cummings, who, strange to say, was a watchmaker. This closet was the first one patented which had what is known as a trap to contain water for a seal. Three

A Bath Room of the Early 70's

years later a patent was issued to Joseph Bramah, inventor of the hydraulic press, for a water closet with a valve at the bottom. Little progress was made in the improvement of water closets during the next half century, and when in the year 1833 the first American patent was taken out the art had not advanced very far. Indeed, it might be said that until the time of the filing of the application for the Fraim and Neff patent, for a siphon closet, that a real cleanly and sanitary type of closet was not on the market.

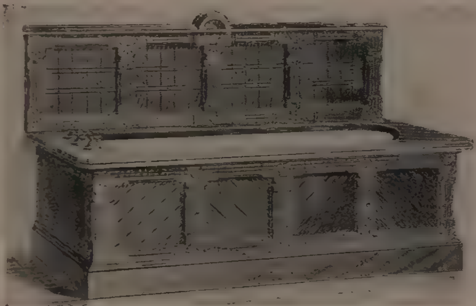


One Stage in the Evolution of the Porcelain Enamel Bath

Bath tubs and lavatories have improved as much in appearance in the time that has elapsed as have water closets. The earliest bath tubs of which we have any knowledge were hewn out of marble. Later, when bath tubs came into rather extensive use in the United States, they were made of wood, lined with either sheet zinc or sheet copper, tinned on one side, and it is only within comparatively recent years that porcelain enameled tubs came into use, and that solid porcelain tubs were manufactured in this country. Open plumbing was unheard of twenty-five years ago and in its stead plumbing fixtures were

A Slop Sink of Long Ago

concealed as much as possible by encasing them in woodwork of more or less ornate designs; at that time the lavatories were all made of marble, and of this material fully 90 per cent. of the lavatories were made up to about the year 1902. About that time, porcelain enameled and solid porcelain lavatories commenced taking the lead and worked a complete revolution in the design of these fixtures. Indeed, so sudden and complete was the change that inside of a year the marble-top lavatories were driven as completely from the market as though they never existed, and, outside of old work, they are as much a curiosity to-day as an old pan closet.



Bath Tub Encased in Woodwork

With the perfecting and cheapening of plumbing fixtures came an increased demand for their use, and the attention of public-minded citizens turned to means for providing the people less favored with worldly riches with means for cleansing the person and apparel. Liverpool, England, was the first of modern cities to establish public

An Old Marble-Top Lavatory

bath houses. The first bath in that city was established in 1828, and is known as the Pierhead. It contains eleven private baths, two vapor baths, one douche, one plunge 46 x 27 feet, one plunge 40 x 27 feet, and two small private plunges. In all, Liverpool has at the present time nine public baths.

Birmingham, England, was next in point of time. It now has five bath houses, the first of which was built on Kent Street, and opened May 12, 1851. In this establishment a Turkish bath can be had for a shilling.

A Modern Porcelain Enameled Lavatory

London, England, follows on the heels of Birmingham, with eleven bath houses, the first of which was erected in 1854. At present municipal London has invested over $2,500,000 in public baths and laundry establishments, which cost $550,000 annually to maintain.

Provisions for free public baths were made in New York in 1870 by the erection of two floating baths. These bath houses, however, could only be used during warm weather, so could not be considered, in the full sense of the word, bathing establishments. The New York Association for Improving the Condition of the Poor, realizing this and the lack of public bathing facilities, undertook to supply the deficiency as far as possible, and in 1891 opened the first real public bath house in the United States, at 9 Centre Market Place. Yonkers, N. Y., however, claims

the credit of being the first city in the United States to establish a municipal bath house, supplied with hot and cold water, open all the year round, and maintained at the public expense.

The example set by a few cities has not been without effect, and other cities in the United States have followed the lead. It is noticeable, however, that it is only in the Eastern cities that public bath houses are built and maintained at the city's expense. According to the "Report on Public Baths and Comfort Stations," Buffalo, Boston, Philadelphia, Newark and Trenton each have one public

Present Stage in the Evolution of Porcelain Enameled Baths

bath house and Chicago has three. Since the publication of that report, however, many cities both in the East and in the West have built public bath houses and many have built, are building, or have planned to build, public comfort stations. Indeed, the standard by which the advancement of cities will be judged in the near future is, "What have they done for the comfort and welfare of the citizens?" And among the visible evidences of what they have done, standing foremost will be the public bath houses, public comfort stations, and last, but not least, public wash houses.

Events of to-day become history of to-morrow, and no history would be complete without recounting contemporaneous facts and events. So it is with sanitation; no history of that subject would be complete without illustrating a few of the plumbing fixtures in use at the time the record

A Twentieth Century Bathroom

was written. We of the present age believe, as did those of a generation ago, that we have almost attained perfection in the manufacture of plumbing fixtures; but have we, or will succeeding generations look back upon what we consider good as we do upon the fixtures in vogue in the early 70's? This we do not know nor can we foresee. Time alone will tell.

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